JOURNAL OF ECONOMIC ENTOMOLOGY
Official Organ American Association of Economic Entomologists

Vol. 35 August, 1942 No. 4

Insect Problems Resulting from Changes in Agriculture in Arkansas

DWIGHT ISELY, *University of Arkansas, Fayetteville*

Extensive changes made during the past decade in acreages of the more important crops of Arkansas, have introduced new insect problems in the state and have made some old problems more difficult. Changes in handling crops have in some cases been as important as changes in acreages themselves. The new host combinations present an unusual opportunity to secure information regarding the effect of various crop arrangements upon insect populations which otherwise might require years of experimental plot work. Such information is of value in determining new problems that must be met. The measures most useful in dealing with some of these problems can be determined only by future research, although a knowledge of the effect of crop combinations may point out how outbreaks may be avoided. The effect of the new agricultural program upon insect problems in the United States has been referred to by Annand (1940), Bishop (1938), and Glick & Ewing (1941).

The most extensive change in proportions of crops has been the reduction in cotton and its replacement by other crops, particularly by legumes. The land in cotton was reduced between 1929 and 1939, from nearly 3,500,000 acres to approximately 2,125,000 (Bryan *et al.* 1941—. The most important replacement has been by soybeans and cowpeas. The increase during this period in acreage of soybeans grown, exclusive of that grown for green manure (according to U. S. Census figures) has been from approximately 34,000 to 596,000. There is also an additional increase of soybeans grown as a soil improving crop, either alone or with corn. Cowpeas increased from approximately 130,000 to 761,000 acres. This is a total of approximately 1,350,000 acres of these two summer legumes and places the acreage of these crops next to those of cotton and corn. The increase in acreage of soybeans is in a way more important since it tends to be concentrated in a few counties in the northeastern Delta. As for instance in a single county, Mississippi, the total acreage in 1939 was 107,000 (Bryan *et al.* 1941). In the part of the Delta where soybeans are most important there have also been large increases in acreages of alfalfa and vetch. In the Ozark counties of northwestern Arkansas which are north of the Cotton Belt the most striking increase has been in lespedeza. During the decade under discussion the reported increase in the state of this crop was from 27,000 acres to 599,000 acres. Corn in the state has increased from approximately 1,866,000 acres to 2,085,000 (Bryan *et al.* 1941), very nearly the same total acreage as is now in cotton. In the Delta the most significant change in corn production is not in the additional acres but in time of planting. When the maximum acreage of cotton was grown most corn was planted in June after cotton chopping. Now much corn is planted before cotton in late March or early April. Oats had increased from 110,000 acres to near 140,000 acres. Since 1939 there has been a great increase in acreage of oats. It has been estimated that over 300,000 acres will be harvested in 1942. The proportional increase in other small grains was for a time greater than that of oats but the total is too small to affect problems except locally. Wheat increased from 17,000 in 1929, to 114,000 in 1934, but dropped to 41,000 in 1939.

The effect of new cropping systems upon insect problems may not be apparent at once. For a given crop pest to occur in excessive numbers, it is essential that its hosts be abundant. Nevertheless even if the hosts are available insect outbreaks are erratic, for favorable climatic conditions and other factors less readily de-

fined are also necessary. Sometimes a period of years may elapse before the conditions essential for an outbreak occur.

In this paper it is not the purpose to discuss pests relatively new in the state which have followed an appreciable increase of a single host, as the hessian fly has followed wheat. Most attention will be given to the effect of combinations of crops on insect problems when the proportion of at least one host has been changed. Only a few illustrations will be discussed.

A striking example of a species of little importance being transformed into a first rate pest by a crop change is the differential grasshopper, *Melanoplus differentialis* (Thos.). Although this species had been recognized as a pest of first rate importance in the southern part of the Great Plains, prior to 1936 it was at worst only a local pest in Arkansas. It had always been more numerous in the Ozarks than elsewhere in the state while in the Delta of northeastern Arkansas it was scarcely more than of common occurrence. A local outbreak was noted in 1930 in the Arkansas river bottoms in the western part of the state where alfalfa production was developing. The numbers of this species were noticeably increasing in some of the valleys of northwestern Arkansas during 1933 and 1934, and in 1935 a few local outbreaks occurred. In 1936 it destroyed thousands of acres of crops in the Ozark counties of the northwestern part of the state, and for the first time appeared in destructive numbers in the Delta counties in the northeastern part. In 1937 control work was undertaken in 25 counties. During that year the pest was particularly injurious in the Delta where it stripped the foliage from several thousand acres of seedling cotton and later caused serious damage to corn. It has been a pest of some importance in the northern counties each succeeding year since that time.

Undoubtedly the vast increase of soybeans changing it from a minor crop to one next in acreage to cotton and corn, was responsible for the change in the status of this grasshopper. This increase has been at the expense of cotton. It has been shown by feeding experiments that cotton as a sole food is unfavorable to this species as indicated by the high mortality, retarded development, and low fecundity of individuals fed solely upon this host (Sanderson 1939). On the other hand using the same critera the soybean was found to be a most favorable host. In spite of the fact that cotton alone was so unfavorable to this grasshopper, the foliage of seedling plants may be destroyed by it in May and June. Under field conditions cotton furnishes only a part of its food. Soybeans and to a lesser extent alfalfa are the hosts upon which its abundance depends. In northwestern Arkansas large acreages of lespedeza in a similar way favor the increase in abundance of the differential grasshopper. Lespedeza and alfalfa have also favored an increase of the lesser migratory grasshopper, *Melanoplus mexicanus* (Riley).

A blister beetle problem is a natural accompaniment of the grasshopper problem. Complaints regarding outbreaks of blister beetles, usually the striped blister beetle, *Epicauta lemniscata* (Fab.), were about 6 times as numerous in 1941 as 10 years earlier. This might be expected since the larvae feed on eggs of grasshoppers, and the adults thrive upon the same hosts that are favored by grasshoppers. The total of the damage which they cause to soybeans and alfalfa does not compare in monetary value with the damage to truck crops caused by migrating swarms.

The chinch bug, *Blissus leucopterus* (Say), is not yet an important pest in Arkansas although in the summers of 1939 and 1940 it attracted more attention than it had during any of the previous 20 years. It had been known as an occasional, local pest during dry summers. The injured spots usually included only a few acres of corn and were widely separated. Most farmers had no acquaintance with it. Perhaps until recently the largest number of injured fields in a limited area occurred in the rice belt. In this region oats and rice are the crops involving the largest acreages, and oats serves as the early spring host and unflooded rice as a summer host. But while neither of these crops is an ideal host the two together nevertheless represented the crop combination which until recently was the most favorable to the chinch bug in Arkansas. Injury to rice has been reported because of its unusualness rather than because of the extensiveness of losses (Isely & Horsfall 1931).

The increase in acreage of small grains which furnish a host for chinch bugs emerging from hibernation might be expected to increase the number of the bugs.

A few instances of severe injury to corn were noted in northeastern Arkansas where corn fields were adjacent to fields of oats. The total acreage of small grain, however, is less than 10 per cent of the total acreage of corn, and its most favored spring hosts, wheat and barley, are only a small part of the small grain acreage.

The change in crop management which appears to have had the greatest effect in increasing the numbers of chinch bugs in northeastern Arkansas is the change in date of planting corn. Corn planted in late March and in April is early enough to attract oviposition of overwintered bugs. Since early planting is a practice which has been adopted by many farmers only after the reduction of cotton acreage, the chance for this type of infestation in the Delta did not occur before that time. Thus far no infestations arising in early corn have been observed which were as destructive as those which migrated from small grains to early corn. As might be expected, interplanting corn with strips of small grain has in a few instances resulted in total loss of the corn but in Arkansas this form of strip cropping does not appear to be common.

The corn rootworm *Diabrotica longicornis* (Say) was sometimes called the northern corn rootworm probably because it was a pest north of the Cotton Belt. Arkansas appeared to be south of its range, and records of its collection in Arkansas in great enough numbers to attract attention have come from a single county bordering Missouri. Recent developments indicate that crop management rather than southern climate have been unfavorable to it. In 1939 in a number of fields in the White River bottoms, 50 per cent or more of the corn stalks fell in midsummer because of injury by the corn rootworm. Upon investigation it was found that these fields had been planted to corn for three years successively. Before the reduction in cotton acreage this land had not produced corn for successive seasons, but as a rule had been given to cotton production. Ten years ago when the acreage of corn was scarcely half that of cotton, corn seldom followed corn. The corn rootworm is still only a local pest but where it does occcur it seems to have a great capacity for destructiveness.

The bean leaf bettle, *Ceratoma trifurcata* (Forst.), has been known for many years as a second rate pest of garden beans cowpeas, and soybeans (Isely 1930). Occasionally it destroyed stands of seedling beans in gardens and more rarely stands of cowpeas. Usually, however, if it attracted attention it was because of holes eaten in the foliage. The larval feeding on the roots and nodules was seldom recognized. As a rule no measures were taken to control this pest. Although cowpeas are a satisfactory host they are usually planted too late to be infested by the overwintered brood. The increase in soybean acreage has changed the status of this species as a pest of snap beans in some communities. Soybeans, unlike cowpeas, may be planted early enough to attract the overwintered beetles. The beetles may not seriously injure this crop but multiply upon it in enormous numbers. For instance, in midsummer in 1940, as many as 1800 beetles were collected in 100 sweeps of a net. The problem suddenly becomes acute when snap beans for the fall market are planted in mid-summer. Soybeans at this time may be maturing or may be cut for hay. The latter forces a migration of beetles from hundreds of acres of soybeans to a relatively small acreage of seedling snap beans. In late July, 1940, entire stands of 4 to 10 acres of seedling snap beans were destroyed in one to four days when the fields were invaded by beetles. While under ordinary circumstances the bean leaf beetle can be controlled by insecticides such an invasion is difficult to control by direct means. Production of large acreages of soybeans in any locality will place a heavy burden upon the success of snap bean production. Possibly the problem would be less difficult if attention were given to timing the planting of soybeans.

The pea aphid, *Macrosiphum pisi* (Kltb.), is common on alfalfa and vetch, and has sometimes destroyed much of the first crop of alfalfa and the crop residue of vetch. It may be questioned if the increase in acreage of these crops resulted in more than a proportionate increase in number of aphids. It has resulted in a greater total population, however, and in wider distribution, and has produced an acute problem in control on a relatively new crop. In 1941 there were about 40,000 acres of alfalfa and 20,000 acres of vetch in Mississippi County. In the same year there were 1,500 acres of garden peas for

commercial production. Producing this crop for the market is relatively recent and began only about five years ago. During the spring of 1941 an unusually severe outbreak of the pea aphid occurred. When the early hosts became less succulent, or when alfalfa was cut, aphid migrations occurred. In some fields the aphids were killed by contact insecticides but the advantage gained by such control was temporary, because the continuous migrations of aphids from the larger acreages of alfalfa and vetch nullified the gains. The loss to the pea crop varied from 50 per cent to total. In this case it was the most recently introduced crop that suffered the heaviest injury. A similar complication of the pea aphid problem has been noted recently in Washington (Eichmann 1940).

Injury to cotton by the bollworm, *Heliothis armigera* (Hbn.), was recorded from twice as many counties in Arkansas in 1941 as during any previous outbreak. More than half the cotton-producing counties were involved, although the distribution was not general over all of these counties and the local damage during other years was more severe. It is not possible to charge this apparent increase of bollworm injury as definitely to a change in crops as the increase in the other pests which have been discussed. The bollworm is always erratic, and its occurrence in outbreak numbers is doubtless affected by climate and many other factors. Nevertheless suitable hosts or host combinations are essential for unusual abundance; and the changes in cropping practices have been favorable to the bollworm. The bollworm is credited with being a rather general feeder but is limited in its host range in that, except for certain legumes, it can develop on only the fruiting parts of most of the plants attacked. The worms cannot develop on the vegetative parts of those favored hosts, corn and cotton, but can develop on the foliage of soybeans, alfalfa, and vetch (Isely 1935). For this reason the vast increases in acreages of soybeans, alfalfa, and vetch, furnish for larvae of the first generation an abundant food supply which was almost entirely lacking ten years ago.

Moths of the bollworm, as is well known, are attracted to fresh corn silks as a place of oviposition in preference to any other host. Also the most favorable larval food is green corn. The extent to which abundance of this host will increase the reproductive capacity of the bollworm is indicated by the effect of food on the rate of larval development and fecundity. Larvae fed on this host at 27° C. become fullgrown in an average of 12.5 days while larvae fed on soybeans at the same temperature require 16 days and on cotton 18 days. Under optimum conditions moths reared from larvae fed on green corn deposit an average of over 1800 eggs, on soybeans over 600, on tomatoes about 200 (Isely 1935). This shows how an abundance of certain hosts may be much more favorable to outbreaks than others. It is obvious that a large acreage of early planted corn which comes into silk in June and July will attract oviposition of first generation moths. Their offspring, the worms of the second generation, will thus have the most favored host for food and this will have an accelerating effect upon the rate of multiplication, and will increase the likelihood of injury to cotton in August and September. On the other hand corn silking from late July until early September is too late to favor multiplication of the second generation, but will actually reduce injury to adjacent cotton since moths will deposit eggs on fresh corn silks in preference to any other host.

The new system of crop arrangement which includes a vast increase in early legumes and earlier planting of corn is most favorable for development of outbreaks of the bollworm and has replaced an arrangement unfavorable to it, particularly in the counties in the Delta of northeastern Arkansas. The same trend has been followed to an extent in all cotton producing counties.

Early maturity of corn has a marked effect on the frequency of occurrence and on the per cent of injury of certain stored grain pests particularly by the rice weevil, *Sitophilus oryza* (L.), and the Angoumois grain moth, *Sitotroga cerealella* (Oliv.). During midsummer when the supply of grain in cribs is normally low, populations of these species usually decline to insignificant numbers. This break in the seasonal food supply is closed by early maturing corn. These insects may migrate from cribs to the field and if corn is mature enough their numbers increase instead of decrease. Ears of early maturing corn which were not harvested until October have been found to have as high as 42 per cent of

their kernels infested by the rice weevil alone. Over 20 per cent infestation is not uncommon.

SUMMARY.—New combinations or changes in proportions of crops in Arkansas have introduced new insect problems and intensified others. If the production of a crop which is a favored host of a given pest is expanded, this pest may incidentally damage less favored hosts in the vicinity. In this manner the great increase in acreage of soybeans and alfalfa has favored abundance of the differential grasshopper and the striped blister beetle. When abundant these pests destroy corn, cotton, pastures or truck crops.

If two or more crops in a vicinity are attractive in succession to a pest, and the crop which serves as the earlier host is the one with the greatly increased acreage, the crop with the smaller acreage may be severely injured as a result of a migration from the earlier host. This is illustrated by the development on soybeans of large populations of bean leafbeetles which migrated to snap beans in midsummer, and of the pea aphid on vetch and alfalfa which migrated to garden peas later in the spring.

Those pests which formerly had satisfactory hosts only during a limited part of the season have recently become more destructive since satisfactory hosts have been grown throughout the season. Thus larger acreages of small grains adjacent to corn and even of early corn adjacent to late corn have favored the chinch bug. The large increase in planting of soybeans and of early corn has made possible a much greater multiplication of the bollworm. Early maturing corn also prolongs the season during which grain infesting pests have abundant food.

A change in crop sequence, resulting from a change in proportionate acreage, like corn after corn, instead of corn and cotton grown in alternate years has developed a new pest problem, that of the corn rootworm, which hitherto had been unwittingly controlled by the rotation practiced.—3-11-42.

LITERATURE CITED

Annand, P. N. 1940. Recent changes in agriculture and their effect on insect problems. JOUR. ECON. ENT. **33**(3): 493–8.

Bishop, F. C. 1938. Entomology in relation to conservation. JOUR. ECON. ENT. **31**(1): 1–11.

Bryan, L. S., J. R. Goodman, and J. R. Grant. 1941. Arkansas Crops and Livestock. Ann Rept. 1940. Agr. Mkt. Ser. U. S. Dept. of Agr.

Eichmann, R. D. 1940 The pea aphid on canning peas in Eastern Washington as influenced by alfalfa plantings. JOUR. ECON. ENT. **33**(1): 137–9.

Glick, P. A. and K. P. Ewing. 1941. Studies of insect damage to cotton with reference to soil conservation practices. JOUR. ECON. ENT. **34**(6): 737–41.

Isely, Dwight. 1930. The biology of the bean leaf beetle. Ark. Agr. Expt. Sta. Bul. **248.**

Isely, Dwight. 1935. Relation of hosts to abundance of cotton bollworm. Ark. Agr. Expt. Sta. Bul. **320.**

Isely, Dwight and W. R. Horsfall. 1931. The chinch bug as a rice pest. Jour. Kan. Ent. Soc. **4**(3): 70–3.

Sanderson, M. W. 1939. Crop replacement in relation to grasshopper abundance. JOUR. ECON. ENT. **32**(4): 484–6.

A. F. BURGESS REPLACED BY RALPH A. SHEALS

A recent press release from the U. S. Department of Agriculture announces the appointment of Mr. Ralph A. Sheals as leader of the Division of Gypsy and Brown-tail Moth Control in the Bureau of Entomology and Plant Quarantine. Mr. Burgess has had charge of the field work on this project for 35 years and entomologists will generally have difficulty in thinking of gypsy moth problems without seeing Mr. Burgess in the Picture. Mr. Burgess is to be assigned special duties in the Bureau and will doubtless welcome the opportunity for semi-relaxation, at least, and relative freedom from responsibility.

In commenting on this change in a letter to the editor, Dr. P. N. Annand, Chief of the Bureau, writes as follows:—

"For some time the Bureau has felt that much valuable information would be lost if Mr. A. F. Burgess, who has devoted nearly 35 years of his life to this work, were permitted to retire without being given the opportunity to bring together in manuscript form his experiences and the many unrecorded observations that he has made in connection with this important work. In addition to compiling this information Mr. Burgess, during the remainder of his active service with the Department, will be available for consultation on this and similar control problems in which the Bureau is participating."

"In assuming administrative direction of the Division of Gypsy Moth Control, Mr. Ralph A. Sheals brings with him a broad experience in quarantine and pest control problems of the Bureau, and a rather intimate knowledge of many phases of the gypsy moth work. For the past several months he has devoted most of his time to becoming acquainted with current problems realting to field operations, and in contacting representatives of Federal and State cooperating agencies."—8-26-42.

Breeding Habits of a Rice Field Mosquito[1]

WILLIAM R. HORSFALL,[2] *University of Arkansas, Fayetteville*

The dominant species of mosquito in the rice-producing areas of Arkansas is *Psorophora confinnis* (Lynch Arribálzaga).[3] Elsewhere in this state and apparently over most of its range in the United States, this species is a pest of minor importance occurring locally or sporadically. In the rice-producing section, however, it occurs all summer as a general pest, and is often present in such numbers that its attacks become almost unbearable.

Conditions of rice culture are suitable for the development of several generations of this species from vast acreages at different times during the growing season. The most obvious favorable condition is that rice is grown on land which is submerged several inches. Since larvae of mosquitoes require the presence of standing water it is natural to suppose that vast hordes of mosquitoes are a direct result. As a matter of fact, submergence alone is not sufficient to produce any numbers of this mosquito, and fields continuously flooded remain free of larvae. In the course of common cultural practice, however, water is drained from fields at least once during the growing season, and usually at this time each field is allowed to dry for two weeks or longer. Sometimes a field is accidentally drained or the water evaporates enough to expose the soil for a few days. Whatever the cause of the soil exposure, a new brood of larvae develops when the fields are reflooded, and reaches maturity within a week or less. This change from a submerged to a drying state provides the condition of most importance in the chain of events which casts this species as the one of greatest abundance in the rice-growing area.

An intervening period of drying of the soil between flooding provides an essential condition in the life history of this mosquito for two reasons. In the first place, this species deposits eggs on moist soil and not on standing water. However, damp soil alone is not suitable, but it together with rank vegetation of a low-growing sort furnishes an ideal oviposition site. In the rice-producing area, such preferred sites are met in greatest acreage in rice fields, less commonly in roadside ditches, and sometimes in uncultivated land subject to overflow. The longer soil remains humid, the longer it is attractive to ovipositing females, hence heavily shaded soil receives more eggs than that not so heavily shaded. The second essential provided by an intervening period of drying is that it permits completion of embryos in eggs of this species. Under normal field conditions, 4 or 5 days are required for embryo perfection, and if the eggs are prematurely submerged or dried, embryos cease growth and soon die. Therefore, slow drying of soil on which eggs have been laid allows ample time for full embryonic development within them. Eggs containing perfected embryos may withstand, if need be, normal unfavorable conditions such as drying or low temperature, for a year or longer.

This species has a short life cycle and may have one or many generations each year. Eggs containing fully developed embryos hatch anytime they are submerged during the summer. Larvae begin to appear in a field within a half an hour after flooding begins, and at the end of 24 hours nearly all have hatched. A week and occasionally less suffices for passage through the aquatic stages. Large fields may require a week to flood them, consequently adults may be emerging from the upper edge of a field while hatching begins along the lower side. Each time suitable oviposition sites are reflooded following drying a new generation of mosquitoes may develop. Schwardt (1939) observed that this mosquito did not breed continuously in rice fields, and as a result, he was led to conclude that rice fields were the source of a relatively small proportion of mosquitoes prevalent in the Arkansas rice sections. His records bearing on this point of necessity were made at irregular intervals and usually showed no larval infestations in fields. However, since the mosquito develops from egg to adult in a week or less, the odds against seeing large numbers of larvae are great except in fields continuously under observation. Hence when the opportunity presented

[1] Research Paper No. 742 Journal Series University of Arkansas. Approved for publication by the Director of the Arkansas Agricultural Experiment Station.

[2] Assisted by Robert W. Anderson, a student.

[3] Formerly called *Psorophora columbiae* (D. & K.) Aitken (1941).

itself in 1940 and 1941, observations were made at regular intervals.

This study was begun with a view of obtaining a plan of reducing the pest mosquito problem by indirect means. The data herein presented point toward this end.

The observations reported in this paper were made during the summer of 1940 in the time when water covered the fields. This means that a rice field does not support continuous broods of this species, but instead it produces isolated broods. As a matter of fact, larvae were abundant only for a week or less in each field at the time of flooding. However, twelve times in 1940 and four times in 1941 larvae were collected during the second or third weeks

Table 1.—Abundance of larvae of *Psorophora confinnis* in rice fields, 1940.

	Number of Larvae in Ten Square Feet										
	Field Number										
Date	1	2	3	4	5	6	7	8	9	10	Total Larvae
5/30	*	*	*	*	*	*	*	*	*	*	0
6/13			*	2	3	*	46				51
6/18			*			*			*		0
6/25	[1]	*	35			95	[1]	[1]	21		151
7/2	110	208	1			1	97	61	1		479
7/9	16	6				5	10	1		[1]	38
7/17					*		7		*	34	41
7/23	[1]		*	[1]	*	*		[1]	*		0
7/30	9	*	*		125	37	[1]	[2]	132		303
8/6		202	235				5	[1]			442
8/13		2	4				1	19			26
8/20				*							0
8/27				12							12
9/2		*				*		*	*		0
Season total	135	418	275	14	128	138	166	81	154	34	1543

* Dry.
[1] Only pools of water present.
[2] Newly emerged adults abundant and pupal exuviae present in water.

rice fields and roadside ditches within a radius of five miles of the Rice Branch Station in Arkansas County, and field records were made again in 1941. Ten fields and 10 ditches were selected at random about the time of planting. These were observed at weekly intervals all summer, and whenever water stood on them, larval counts were made at 10 separate stations in each. At each station, the larvae in one square foot were counted. A cylindrical screen counting chamber with a cross-sectional area of 1 square foot was used to enclose only those larvae within this area. By means of a tea strainer the larvae were removed and counted. The results are recorded in the following tables.

Data in tables 1 and 2 show that in the case of ten fields regularly observed for two years, larvae were collected only 53 times out of a total of 210 times when fields were flooded. Larvae of this species, therefore, were present only one-fourth of after flooding, but these collections were always small.

Tables 1 and 2 show that larvae were most abundant when water was added to fields which previously had been thoroughly dried. Collections were largest in those fields which had dried to the point of cracking of the soil and least numerous in those which had dried only partially. As an average, the larval population for each period of abundance varied between six and 20 larvae to a square foot and, in one field in 1941, an average of 45 larvae to a square foot were observed. From two fields each year very few larvae were collected. One of these (1 in table 2) was never drained; another (4 in table 2) was planted very late and was never fully flooded until after the peak of adult abundance; and the other two (4 and 10 in table 1) were never dried thoroughly during the periods of adult abundance. Therefore each year some fields may be expected to produce few larvae because of irregular

Table 2.—Abundance of larvae of *Psorophora confinnis* in rice fields, 1941.

Date	Number of Larvae in Ten Square Feet										Total Larvae
	Field number[4]										
	1	2	3	4	5	6	7	8	9	10	
5/26	*	*	*	*			3	5	12	*	20
6/3		*	*	*	1			1		2	0
6/11	1	1	*	*	1	1	1	*	*	16	17
6/18			4	*	*	104	348	452	*	*	908
6/25		*	3	*	241		5	18	220	367	854
7/1		*		6		2					8
7/8		67	*	*	1						67
7/15			52		230						282
7/23				*							0
7/30				6							6
8/5											0
8/12											0
8/19						1					1
8/26						*		3			0
Season total	1	67	59	12	471	107	356	475	232	383	2163

* Dry.
[1] Drying, nearly dry.
[2] Field flushed.
[3] Field drained for harvest.
[4] Field numbers are not same as 1940.

methods of handling the water.

During both of these years, a tenth-acre plot was kept continuously flooded all summer as a check against field variation. Water was often added as evaporation or seepage lowered the level, and at no time was the soil exposed. As in the case of the fields, observations were made at weekly intervals. No larvae of this or any other flood-water species were ever observed in the plot.

Ditches are not as dependable breeding places for *Psorophora confinnis* as are the rice fields. When compared on an equal area basis ditches are less important as may be seen by comparing the season

Table 3.—Abundance of larvae in ditches, 1940.

Date	Number of Larvae in Ten Square Feet										Total Larvae
	Ditch number										
	1	2	3	4	5	6	7	8	9	10	
5/30	180	2		23		*		98	7	*	310
6/13	*		*	*		*	*	*	*	*	0
6/18	*		*	*		*	*	*	*	*	0
6/25	*	*	*	*		*	*	*	*	*	0
7/2	10	23		13	9	1	9	77	4	1	145
7/9	16		1	20[2]	1		18		19	*	74
7/17	1				1		22	2	1	1	27
7/23	*	2	1			*	*			*	0
7/30	2[2]	*	*			*	*		*	*	2
8/6	*	*	*	*		*	*	*	*	1	0
8/13	3	46		3		*	*	*	*	1	49
8/20	*	*	1	*		*	*	*	*	*	1
8/27	*	*	*	1[4]		*	*	*	*	*	1
9/2	*	*	1		*	*	*	*	*	*	0
Season total	209	71	2	60	10	0	49	177	31	0	609

* Dry.
[1] Water flowing rapidly.
[2] Adjacent field being drained into ditch.
[3] Ditch disked and harrowed.
[4] Seepage from adjacent field partly flooded ditch.

totals of 1543 larvae for the fields in table 1 and 609 larvae for the ditches in table 3. Of course, only those ditches that are intermittently flooded may become breeding places of this species. Naturally most of this intermittent flooding occurs most often early in the season as a result of seepage, drainage of fields, or rain. Later most of them are dry. Of the 10 observed in 1940, numbers 3, 6, and 10 had sufficient fall to cause rather quick run off, and larvae did not mature before they were carried down to larger streams where fish might reach them. Almost permanent flooding is not conducive to larval development, because, as was the case with No. 5 in table 3, fish were present and destroyed larvae that may have hatched and washed in from elsewhere.

A comparison of the ditch area in acres and the rice field area in acres for the prairie section of Arkansas County shows that ditches are secondary as a source of *Psorophora confinnis*. In the prairie region of the county, there are 611[1] miles of section line roads with their accompanying ditches. The right-of-way is about 40 feet wide making a total of 2958 acres of land devoted to right-of-way. One-half of this, or 1479 acres, may be allowed the ditches and their immediate drainage area, an allowance which is considered ample since many of the section lines are not graded, and many of those that are graded have considerably less than half the width of the right-of-way devoted to them. In 1940, Arkansas County alone grew 71,574[2] acres of rice which is an area about 48 times greater than the possible ditch area. The season total of larvae collected in 100 square feet of field area was 1543, and in 100 square feet of ditch area it was 609, or season means of 15 ± 4 larvae per square foot in the fields and 6 ± 2 larvae per square foot in the ditches. In other words, the ratio of productivity per unit area is 15 to 6 in favor of the fields. If the product of the field area and its factor, 15, is divided by the product of the ditch area and its factor, 6, the relative productive value of the field area and ditch area can be expressed. In this case, the relative productive value is 120 which means that the fields are 120 times as important as the ditches as sources of *P. confinnis* larvae. Even early in the season when the ditches contain more larvae than later, the productive capacity of the larger number of poorly prepared fields vastly exceeds that of the ditches. While this does not mean that roadside ditches are of no importance when control is considered, it does mean attention must be given fields first and ditches second.

[1] Calculated from a detailed county map.
[2] Data furnished by Mr. G. W. Sorrells, County Agent, Arkansas County.

In an effort to determine the influence of ground cover on abundance of larvae, observations were made during midsummer in a tenth-acre plot seeded to three stands of rice. Each density was represented in three different places in the plot making a total of nine plantings. In addition, three bare areas were maintained. Before the mid-summer flooding began nine pieces of sheet metal arranged to form hollow squares three feet on a side were set into the nine subplots, and three others were put in the bare areas. When they were flooded, each area contained only those larvae that hatched in it. Four days later the larvae in one square foot were counted by using the square-foot counting chamber. In table 4 below the results are shown.

Table 4.—Influence of vegetation on abundance of larvae of *Psorophora confinnis*,[1] 1940.

	Soil Cover			
	Rice Light Stand[2]	Rice Medium Stand[3]	Rice Heavy Stand[4]	Bare
Number of larvae per 3 square feet	254	171	243	12

[1] Plot records made in late summer.
[2] Average number of plants per 10 feet of drill row—151.
[3] Average number of plants per 10 feet of drill row—185
[4] Average number of plants per 10 feet of drill row—201.

Table 4 shows clearly that while areas devoid of vegetation may act as breeding places for *Psorophora confinnis* when flooded, those areas on which vegetation such as rice grows are much more important. The bare areas may have about four larvae to a square foot as against 60 or 80 in adjacent rice fields flooded at the same time. It seems that the variations in stand within normal field limits have no influence on the numbers of larvae that may develop on a field.

SUMMARY.—*Psorophora confinnis* a flood-water mosquito common all over Arkansas, is the most important pest-species in the rice-growing areas of the

state. It occurs all summer as a general pest, and at times livestock suffers severely.

Conditions of rice culture are suitable for the development of several generations or broods from vast acreages at different times during the growing season. Larvae are not continuously present in the fields but are found only at times of reflooding following drainage. A vegetative covering on the soil provides shading of the soil and thereby provides the most suitable breeding places during the summer. Larvae have been found in flooded areas with no vegetative cover, but few were found in such areas in rice fields.

Roadside ditches are not dependable summer breeding places for this species, because they are usually dry or remain permanently flooded and are stocked with minnows. Larvae have been collected in ditches following rains, field drainage, and field seepage especially early in the season. However, ditches are less important than fields because the total area and productive capacity is much less.—2-11-42.

LITERATURE CITED

Aitken, T. H. G. 1941. The genus Psorophora in California (Diptera, Culicidae). Rev. de Ent. **11**: 672–82.

Schwardt, H. H. 1939. Biologies of Arkansas rice field mosquitoes. Arkansas Agr. Expt. Sta. Bul. **377**.

Relation of Fertilizers to the Development of the Cotton Aphid

R. L. McGARR, *U. S. Department of Agriculture, Bureau of Entomology and Plant Quarantine*[1]

Observations have indicated that the use of nitrogenous fertilizers or nitrogen-producing crops on land planted to cotton stimulates the development of the cotton aphid, *Aphis gossypii* Glov., when calcium arsenate is used for the control of other insects. The more general use of fertilizers and soil-improving crops in recent years is apparently a factor in the increased seriousness of the cotton aphid, and an experiment was conducted at State College, Miss., in 1941 to obtain more definite information on the relation of nitrogen in the fertilizer to the abundance of aphids. The build-up of aphids on cotton following treatment with calcium arsenate dust and fertilizers containing different amounts of nitrogen, but fairly constant amounts of phosphoric acid and potash, was compared with that following treatment with calcium arsenate dust alone, fertilizer alone, and no treatment.

Land was selected that was in a fair state of production and on which no fertilizers had been used in recent years. The fertilizers were factory-mixed and were applied at the rate of 600 pounds per acre on April 7 and 10, just prior to the planting of the cotton.

The treatments were tested in 6 randomized blocks, 3 of which were located in each of 2 fields on the same farm. Each block was divided into 7 plots, one for each treatment. The plots were 12 rows in width and of sufficient length to make one-tenth acre. Applications of calcium arsenate dust were made as nearly as possible at 5-day intervals, beginning on June 25, which was about the time the first blooms appeared on the cotton. A total of 8 applications were made by July 28, 2 of which were washed off by rain within 24 hours and were not considered effective. The applications were made with single-row rotary hand guns early in the morning or late in the evening at the rate of approximately 6 pounds per acre per application.

Infestation records were made for aphids and boll weevils at approximately weekly intervals on the 6 center rows of each plot, the first records being made on the day prior to the initial dust application. Seven aphid and 5 boll weevil records were made after dusting had started. The aphid records for each plot were made by counting the aphids per square inch on 100

[1] In cooperation with the Mississippi Agricultural Experiment Station and the Mississippi State Plant Board. J. C. Redd and W. R. Smith assisted in making the field records. Analyses of the fertilizers were made through the courtesy of the Mississippi State Department of Agriculture and the State Chemist. Thanks are due to A. L. Hamner of the Mississippi Experiment Station, for supervising the application of the fertilizers during the writer's absence and to R. C. Gaines for making the statistical analysis.

Table 1.—Cotton aphid populations and boll weevil infestations following different treatments. Averages of six small plots.

Treatment		Active Fertilizer Ingredients			Calcium Arsenate per Acre per Application	Aphids per Sq. Inch Leaf Area		Average Seasonal Boll Weevil Infestation
Fertilizer	Calcium Arsenate	Nitrogen	Phosphoric Acid	Potash		Maximum	Average	
					Pounds	*Number*	*Number*	*Per Cent*
Present	Present	0%	8.15%	4.19%	6.0	34.28	6.75	19.9
		2.29	8.60	3.49	5.9	45.08	8.34	22.3
		4.08	8.15	4.17	6.2	48.48	8.88	19.0
		6.53	10.65	3.60	5.8	55.66	9.76	20.0
Present	Absent	6.53	10.65	3.60	0	5.75	1.07	40.0
Absent	Present	−0	−0	−0	6.2	30.49	6.05	19.0
Absent	Absent	−0	−0	−0	−0	4.59	.91	36.1
Minimum significant difference:								
5 per cent level							2.36	3.1
1 per cent level							3.19	4.2

square inches of leaf area on the underside of the fourth leaf from the top of the plants. Records on the boll weevil were obtained by examining 100 squares per plot for feeding and egg punctures at each examination. No yield records were made in the plots.

The different treatments used and the average seasonal aphid and boll weevil infestations are shown in table 1.

The increase in aphids was slow in all the plots for approximately a month after dusting began and was then very rapid in the dusted plots. The average aphid populations per square inch of leaf area for the last four examinations, which were made after the increases began in the dusted plots, are shown in fig. 1.

The results indicated that nitrogenous fertilizer caused a definite increase in aphids when the cotton was dusted with calcium arsenate, but it caused no appreciable increase when calcium arsenate was not used. Dusting with calcium arsenate caused a significant increase in aphids in all tests, but where both fertilizer and calcium arsenate were applied the increase was greater and roughly in proportion to the nitrogen content of the fertilizer—2-27-42.

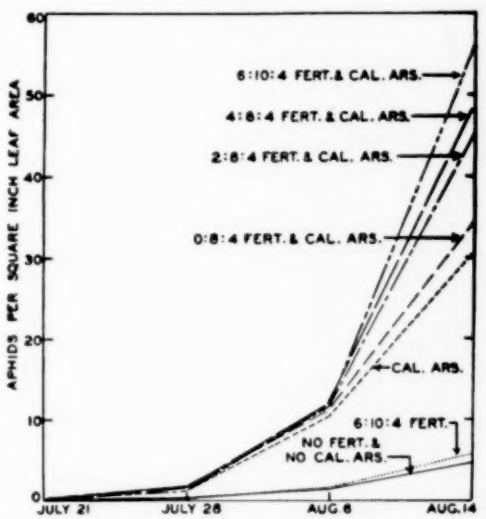

FIG. 1.—Average cotton aphid populations per square inch of leaf area for six replications of the various treatments.

LIEUTENANT H. E. MILLIRON

Dr. Herbert E. Milliron, for the past few months on the staff of the Purdue Agricultural Experiment Station, Lafayette, Indiana, has accepted a commission as a First Lieutenant in the Sanitary Corps and is stationed, at present, at Camp Grant, Rockford, Illinois. Lieutenant Milliron states that his work is to be entirely entomological, his status being, apparently, that of a medical entomologist. This is evidence of the effective work of some of our committees in securing adequate recognition of the importance of entomological work in maintaining health and comfort in the army.

Experiments on Time to Begin Dusting with Calcium Arsenate and Number of Applications for Boll Weevil Control

M. T. Young, G. L. Garrison, and R. C. Gaines, *U. S. Department of Agriculture, Bureau of Entomology and Plant Quarantine*[1]

Studies were conducted near Tallulah, La., in 1940 and 1941 to obtain information on the time to begin dusting with calcium arsenate and the number of applications for the most economical boll weevil control in that locality. Applications beginning when 10 per cent of the squares were infested and continuing at 4- or 5-day intervals as long as needed, in accordance with the usual recommendations, were compared with a smaller number of applications beginning at different infestation levels and at the time of weevil migration. The general movement, or dispersal, of weevils between fields often causes a sudden increase in damage in fields that were only lightly infested before migration occurred, and it is sometimes difficult to determine whether it would be profitable to continue dusting or to begin dusting in fields subject to reinfestation.

Plots, Treatments, and Records.—In 1940 the plots were 20, 22, or 24 rows in width and of sufficient length to make at least one-fourth acre. Areas 5 rows wide on each side and 17.5 feet or more on each end of each plot were marked off as buffers, and yield records were taken on the remaining one-tenth acre. In 1941 the plots were either 20 or 22 rows in width and of sufficient length to make at least one-fourth acre. Buffer areas of 8 or 9 rows on each side and 17.5 feet or more on each end were marked off, and cotton was picked on the remaining one-thirtieth or one-twenty-fifth acre. Each year the plots were arranged in randomized blocks.

Six experiments were conducted. In experiments 1 and 2 the following dusting schedule was used: Six applications beginning at 10-per cent square infestation, three of which were applied before and three starting when summer dispersal, or migration, of boll weevils began; three applications at 10-per cent square infestation and before migration; one, two, and three applications beginning when migration started; and no treatment. In experiments 3, 4, and 5 dusting was begun at different infestation levels. In experiment 6 one, two, and three applications were made beginning at migration. Only effective applications, those not washed off by rain within 24 hours, are considered.

Experiments 1 and 2 were similar, but were given different numbers since they were located in separate fields. The same is true of experiments 4 and 5. All replicates in experiments 3 and 6 were located in one field.

Calcium arsenate was applied with single-nozzle rotary hand guns at 4- or 5-day intervals during the early morning, when the plants were usually wet with dew and the atmosphere was calm. Within an experiment calcium arsenate was applied as nearly as possible at the same rate per acre in all tests. The material used in 1940 contained on an average 42 per cent of total arsenic pentoxide and 6.4 per cent of water-soluble arsenic pentoxide (New York method). In that year the average number of pounds used per acre per application ranged from 6.9 to 7.6 in experiment 1, from 5.9 to 6.3 in experiment 2, from 7.6 to 8.7 in experiment 3, and from 7.4 to 8.6 in experiment 6. The material used in experiments 1 and 2 in 1941 contained on an average 42.5 per cent of total arsenic pentoxide and 7.2 per cent of water-soluble arsenic pentoxide (New York method), and the average quantity used per acre per application ranged from 5.6 to 7.9 pounds in experiment 1 and from 6.1 to 8.0 pounds in experiment 2. The material used in experiments 4 and 5 in 1941 contained on an average 41.7 per cent total, and 9.5 per cent of water-soluble, arsenic pentoxide (New York method), and the average quantity used per acre per application ranged from 6.0 to 6.1 pounds in experiment 4 and from 6.4 to 6.5 pounds in experiment 5.

In 1940 boll weevil infestation records were made by counting the egg and feeding punctures on 300 squares on the 2

[1] The authors were assisted in the field-plot experiments by G. D. Green, G. H. Rainwater, J. E. Gillaspy, W. A. Lee, T. F. Henderson, and R. R. Coffin. All chemical analyses were furnished by the Division of Insecticide Investigations, Bureau of Entomology and Plant Quarantine.

middle rows, 100 near the center and 100 near each end. In 1941 these records were made by counting the egg and feeding punctures on 200 squares on the 10 middle rows in 20-row plots and on the 12 middle rows in 22-row plots. In a 22-row plot the first record was made on 6 rows to the right of the center by taking approximately one-third of the squares near the end of the first and second rows, one-third near the middle on the third and fourth rows, and the remainder near the opposite end on the fifth and sixth rows. In a 20-row plot one-third of the squares were taken on the first and second rows, one-third on the third row, and the remainder on the fourth and fifth rows. A second record was made in the same manner but to the left of the center. By use of this method approximately the same cotton was used on alternate weeks. The percentages were transformed to equivalent angles for use in the analysis of variance. The percentages corresponding to the mean angles are also presented.

Damage from cotton aphids was eliminated in experiments 1, 2, 3, and 6 by applying a mixture of hydrated lime and 40-per cent nicotine sulfate, which contained 3 per cent of nicotine, as an aphicide. Aphids were not controlled in experiments 4 and 5.

RESULTS.—The results of the six experiments, together with the analysis of variance, are presented in table 1. The minimum significant differences required at the 5- and 1-per cent levels are given where the *F* test indicated that there were significant differences between the treatment means of infestations and yields.

In 1940 calcium arsenate did not significantly reduce the boll weevil infestation as compared with the checks in experiment 1, but there were significant reductions in experiment 2. Six applications, three before and three after weevil migration, made from July 24 to August 20, were followed by an average increase over the checks of 565 pounds of seed cotton per acre in experiment 1, 330 pounds in experiment 2, and 424 pounds in both experiments. Three applications before migration, made from July 24 to August 3, were followed by an average increase over the checks of 215 pounds of seed cotton per acre in experiment 1, 90 pounds in experiment 2, and 140 pounds in both experiments. Three applications after migration, made from August 7 to 20, gave an average increase over the checks of 320 pounds per acre in experiment 1, 340 pounds in experiment 2, and 332 pounds in both experiments.

In 1941 six applications of calcium arsenate, three before and three after weevil migration, made from July 15 to August 15, were followed by an average increase over the checks of 420 pounds of seed cotton per acre in experiment 1, 753 pounds in experiment 2, and 588 pounds in both experiments. Three applications before migration, made from July 15 to 30, were followed by an average increase over the checks of 138 pounds of seed cotton per acre in experiment 1, 363 pounds in experiment 2, and 251 pounds in both experiments. Three applications after migration, made from August 3 to 15, gave an average increase over the checks of 249 pounds of seed cotton per acre in experiment 1, 255 pounds in experiment 2, and 252 pounds in both experiments.

The average increase in yield in experiments 1 and 2 during the 2 years was 506 pounds of seed cotton per acre for six applications, 196 pounds for three applications before migration, and 292 pounds for three applications after migration.

Applications of calcium arsenate beginning at 8-per cent infestation (July 24) and at 25-per cent infestation (August 13) were followed by significantly greater yields than applications beginning at 70-per cent infestation (August 17), but the differences between the yields following applications beginning at 8- and 25-per cent infestation were not significant. Each of the three treatments gave a highly significant increase over the checks. Eight applications beginning with an 8-per cent infestation gave an average increase in yield over the checks of 522 pounds of seed cotton per acre, five applications beginning with a 25-per cent infestation an increase of 580 pounds, and four effective applications beginning with a 70-per cent infestation an increase of 350 pounds.

In experiment 4 applications beginning at 30- to 40-per cent square infestation (July 23) and at 50- to 60-per cent infestation (July 28) gave greater yields than the checks. In experiment 5 highly significant increases of 231 and 192 pounds of seed cotton per acre over the checks followed applications beginning at 30- to 40-per cent infestation (July 13) and at 50- to

Table 1.—Results of field experiments against the boll weevil with various calcium arsenate treatments, together with statistical analyses.

Number of Applications and When Begun	Boll Weevil Infestation (Per Cent)		Boll Weevil Infestation (Angle)		Pounds of Seed Cotton per Acre		Analysis of Variance			
									Mean Square Pertaining to	
	1940	1941	1940	1941	1940	1941	Year and Source of Variation	Degrees of Freedom	Infestation (Angle)	Yield, 1/10 Acre in 1940 and 1/30 Acre in 1941
Experiment 1:										
Check	72	67	57.8	54.9	1005	1341	1940:			
6 at 10% infestation (3 before and 3 after migration)	63	52	52.3	46.2	1570	1761	Blocks	1	6.85	242.00
3 at 10% infestation, before migration	70	46	56.6	42.5	1220	1479	Treatments	3	18.70	1102.33
3 at migration	74	58	59.4	49.8	1325	1590	Error	3	16.93	185.67
2 at migration	—	58	—	49.4	—	1569	1941:			
1 at migration	—	66	—	54.6	—	1539	Blocks	2	3.76	0.39
Minimum significant difference:							Treatments	5	69.13[2]	63.42
5% level			—	6.2	—	—	Error	10	11.54	24.86
1% level			—	8.8	—	—				
Experiment 2:										
Check	69	72	56.3	58.2	1253	858	1940:			
6 at 10% infestation (3 before and 3 after migration)	27	29	31.1	32.6	1583	1611	Blocks	2	32.74	321.33
3 at 10% infestation, before migration	56	48	48.5	43.9	1343	1421	Treatments	3	356.37[2]	882.00[2]
3 at migration	41	71	39.8	57.1	1593	1113	Error	6	11.58	57.33
2 at migration	—	69	—	55.9	—	1161	1941:			
1 at migration	—	67	—	54.7	—	1068	Blocks	2	33.19	111.72
Minimum significant difference:							Treatments	5	307.96[2]	206.04[2]
5% level			6.8	9.1	151	153	Error	10	25.16	7.99
1% level			10.3	13.0	229	219				
Experiment 3:										
Check	87	—	69.2	—	638	—				
8 at 8% infestation	44	—	41.6	—	1160	—	1940:			
5 at 25% infestation	53	—	46.7	—	1218	—	Blocks	3	41.79	170.06
4 at 70% infestation	71	—	57.3	—	988	—	Treatments	3	598.16[2]	2726.23[2]
Minimum significant difference:							Error	9	20.67	113.56
5% level			7.3	—	170	—				
1% level			10.4	—	245	—				
Experiment 4:										
Check	—	68	—	55.3	—	1650				
6 at 30 to 40% infestation	—	49	—	44.7	—	1440	1941:			
5 at 50 to 60% infestation	—	38	—	38.1	—	1539	Blocks	1	55.69	0.00
Minimum significant difference:							Treatments	4	175.78[1]	20.65
5% level			—	11.3	—	—	Error	4	16.55	26.25
1% level			—	18.7	—	—				
Experiment 5:										
Check	—	71	—	57.5	—	789				
6 at 30 to 40% infestation	—	40	—	39.4	—	1020	1941:			
5 at 50 to 60% infestation	—	64	—	53.4	—	981	Blocks	2	4.07	5.27
Minimum significant difference:							Treatments	4	229.81[2]	117.07[2]
5% level			—	8.7	—	99	Error	8	21.18	3.02
1% level			—	12.6	—	144				
Experiment 6:										
Check	75	—	60.0	—	1133	—				
1 at migration	79	—	63.0	—	1203	—	1940:			
2 at migration	65	—	53.7	—	1345	—	Blocks	3	129.40	75.23
3 at migration	49	—	44.3	—	1393	—	Treatments	3	271.58[1]	587.73[2]
Minimum significant difference:							Error	9	54.86	69.51
5% level			11.8	—	133	—				
1% level			17.0	—	192	—				

[1] Significant. [2] Highly significant.

60-per cent infestation (July 22), respectively. When the yields of experiments 4 and 5 were combined, nonsignificant increases of 54 and 66 pounds of seed cotton per acre were found for treatments begun at 30- to 40-per cent and at 50- to 60-per cent infestation, respectively.

In 1940 one application beginning at migration (August 6) gave a nonsignificant increase in yield over the checks of 70 pounds of seed cotton per acre, and two and three applications gave highly significant increases of 212 and 260 pounds, respectively. In 1941 one, two, and three applications beginning at migration (August 3) gave highly significant increases over the checks of 204, 267, and 252 pounds of seed cotton, respectively. When the data for 1940 and 1941 were combined, one application beginning with migration gave an increase in yield over the checks of 137 pounds of seed cotton per acre, two applications 239 pounds, and three applications 256 pounds.—2-10-42.

Boll Weevil Control with Calcium Arsenate Applied at Different Times of Day and at Different Time Intervals

M. T. Young, G. L. Garrison, and R. C. Gaines, *U. S. Department of Agriculture, Bureau of Entomology and Plant Quarantine*[1]

This paper presents the results of two series of experiments conducted near Tallulah, La., from 1934 to 1941, comparing the control of the boll weevil, *Anthonomus grandis* Boh., obtained by applications of calcium arsenate dust at different times of the day and at different time intervals between applications. In one series of experiments plots were dusted with calcium arsenate at either 4- or 5-day intervals between daybreak and 7:00 a.m., between 1:00 and 3:00 p.m., and between 6:00 and 7:30 p.m. In the other series of experiments plots were dusted with calcium arsenate in the early morning at 4-, 6-, and 8-day intervals. The results obtained in the time-of-day experiment in 1939 have been reported (Young *et al.* 1940).

Plots.—The plots used from 1934 to 1938, including buffer areas, were 20 to 24 rows in width and of sufficient length to be three-fourths acre or more in area. The buffer areas consisted of 5 rows on each side and at least 25 feet across each end The entire plots were dusted, but all infestation and yield records were made on the one-fourth acre areas within the buffers. The plots were arranged in series and parallel to one another, and treatments were not assigned at random. In 1939, 1940, and 1941 the plots were approximately one-fourth acre in size and were arranged in randomized blocks. In 1939 and 1940 the buffer areas consisted of 5 rows on each side and at least 17.5 feet on each end, and records were taken on one-tenth acre areas within the buffers. In 1941 the yield records were made on the 4 middle rows, or one-thirtieth acre. Since it was not always possible to obtain the desired number of replications in one field, it was sometimes necessary to use two or more fields.

Records.—All squares containing either feeding or egg punctures were considered as weevil-infested. In the experiments conducted from 1934 to 1938, inclusive, boll weevil infestation records were made by examining 200 squares in the middle of each plot and 200 near the middle of each end, or a total of 600 squares per plot. In 1939 and 1940 the infestation records were made in the same manner except that 100 squares were examined at each of the 3 locations. The plants were taken consecutively on the 2 middle rows of the plot at each point, and every square of a plant that was large enough to be punctured by a boll weevil was examined until the desired number of squares were obtained. In 1941 infestation records were made by examining 200 squares in each plot. On the first record, approximately one-third of these were examined near the end of the first and second rows to the right of the center, one-third near the center on the third and fourth rows from the center, and the remaining third near the opposite end on the fifth and sixth rows from the center. The second record was made in the same manner but to the left of the center. By use of this method approximately the same cotton was used every 2 weeks, and the samples were taken over a larger area than in previous years.

Yield was the total amount of seed cotton produced on the area within the buffers of each plot.

Treatments.—A record of the quantity of calcium arsenate applied to each plot was obtained by weighing the single-nozzle rotary hand dust gun before and after each application. All treatments were begun when approximately 10 per cent of the squares had become infested. Whenever a treatment was washed off by rain within 24 hours after application, it was considered ineffective and another was made as soon as possible. During the 6 years (1934, 1935, and 1938–41) in which the time-of-day esperiments were made the average quantities of calcium arsenate used per acre per application on the early-morning, the midday, and the late-afternoon treatments were 6.5, 6.4, and 6.1 pounds, respectively. The number of applications for the three treatments averaged 9.5, 8.3, and 7.3, 6.8 being effective in each. During the 8-year period in which the time-interval experiments

[1] The authors were assisted in the field by G. D. Green, G. H. Rainwater, J. E. Gillaspy, W. A. Lee, H. W. Frings, H. C. Massey, C. A. Richmond, G. A. Thompson, Jr., R. W. Goins, K. H. Smith, C. L. Smith, T. F. Henderson, G. M. Webb, J. M. Yeates, and R. R. Coffin.

Table 1.—Average yield of seed cotton per acre obtained from plots dusted with calcium arsenate at different times of the day.

Year	Check	Dusted at Indicated Time of Day		
		Early Morning	Midday	Late Afternoon
	Pounds	*Pounds*	*Pounds*	*Pounds*
1934	1,365	1,444	1,269	1,444
	1,037	1,373	1,117	1,107
	1,190	993	1,291	996
Average	1,197	1,271	1,226	1,182
1935	1,718	2,009	2,122	1,874
	765	715	778	768
	849	905	949	929
Average	1,111	1,210	1,283	1,190
1938	1,680	1,876	1,789	1,893
	1,827	2,048	1,828	2,023
	2,380	2,422	2,417	2,502
Average	1,962	2,115	2,011	2,139
1939	1,840	2,080	2,460	2,110
	2,390	2,930	2,610	2,570
	1,340	1,650	1,600	1,710
	1,680	2,570	2,380	2,280
Average	1,813	2,308	2,263	2,168
1940	1,210	1,880	1,760	1,730
	1,110	1,640	1,850	1,860
	1,170	1,790	2,150	1,690
	1,290	1,960	2,090	1,930
	1,230	1,790	1,860	1,570
	1,320	1,960	1,870	1,940
Average	1,222	1,837	1,930	1,787
1941	1,080	1,380	1,350	1,320
	960	1,350	1,590	1,320
	1,200	1,830	1,710	1,770
	1,320	1,680	1,740	1,860
Average	1,140	1,560	1,598	1,568
Average for all years	1,408	1,717	1,719	1,672
Increase		309	311	264

were conducted the average quantities of calcium arsenate used per acre per application on the 4-, 6-, and 8-day-interval treatments were 6.2, 6.3, and 6.2 pounds, respectively. The average numbers of effective applications were 6.2: 4.5: and 3.5, whereas the average total applications were 7.6, 5.7, and 4.6. Standard calcium arsenate was used in all experiments.

RESULTS.—The average square infestation after treatment was begun in the

Table 2.—Average yield of seed cotton per acre obtained from plots dusted with calcium arsenate at different time intervals.

Year	Check	Dusted at Indicated Time Interval		
		4-day	6-day	8-day
	Pounds	*Pounds*	*Pounds*	*Pounds*
1934	1,082	1,139	1,065	1,109
	854	960	963	1,000
	1,173	1,369	1,352	1,245
	1,572	1,556	1,360	1,212
Average	1,170	1,256	1,185	1,142
1935	732	847	727	664
	1,948	1,833	1,761	1,850
	1,526	1,530	1,543	1,613
Average	1,402	1,403	1,344	1,376
1936	2,749	2,918	2,835	2,918
	2,519	2,320	2,555	2,230
	2,075	2,362	2,189	2,307
	2,552	2,536	2,364	2,412
	2,706	2,644	2,496	2,790
Average	2,520	2,556	2,488	2,531
1937	3,154	3,068	2,823	2,777
	3,129	2,517	2,805	2,905
	2,218	2,569	2,434	2,273
Average	2,834	2,718	2,687	2,652
1938	2,127	2,322	2,400	2,381
	2,027	2,233	2,245	2,308
	2,210	2,323	2,172	2,013
Average	2,121	2,293	2,272	2,234
1939	1,050	1,450	1,060	1,330
	1,360	1,720	1,290	1,770
	870	1,370	1,170	1,570
	990	1,050	1,460	730
	2,340	2,900	2,810	2,550
Average	1,322	1,698	1,558	1,590
1940	630	1,430	1,430	990
	460	1,360	1,210	1,180
	680	1,510	1,320	750
	640	1,120	930	1,020
	920	1,360	1,330	1,260
	750	1,450	1,110	1,130
Average	680	1,372	1,222	1,055
1941	1,080	1,380	1,380	1,110
	960	1,350	1,560	1,230
	1,200	1,830	1,590	1,800
	1,320	1,680	1,800	1,500
Average	1,140	1,560	1,583	1,410
Average for all years	1,649	1,857	1,792	1,749
Increase		208	143	100

23 replications of the time-of-day experiments was 38.4 per cent for the untreated checks, 13.4 per cent for early-morning, 20.0 per cent for midday, and 20.6 per cent for late-afternoon applications. The square infestations were light during the greater part of the fruiting seasons of 1934, 1935, and 1938, and the differences between the yields in the treated and check plots were small. The square infestations were heavier during the fruiting seasons of 1939, 1940, and 1941, and the increased yields of the treated plots over the checks were great, but no outstanding differences between the early-morning, midday, and late-afternoon applications were shown.

The yield records are given in table 1. Applications of calcium arsenate during the early morning gave an average increase over the checks of 309 pounds of seed cotton per acre, applications near midday 311 pounds, and those during the late afternoon 264 pounds.

The average square infestations after treatment was begun in the 33 replications of the time-interval experiments were 36.4 per cent, 17.8 per cent, 21.2 per cent, and 22.5 per cent in the untreated and the 4-, 6-, and 8-day interval-treated plots, respectively.

The yield records for the 8-year period 1934–41 are given in table 2. The weevil infestations were light during the greater part of the fruiting seasons of 1934 to 1937, inclusive, and in each season the differences between the yields of the treated and untreated plots were small. The infestation was somewhat higher in 1938, and the increased yields for the treated plots were greater. The infestations were much heavier in 1939, 1940, and 1941, and in most experiments the increased yields of the treated plots over the checks were much greater than during any year of the 1934–38 period. The greatest increased yields for the treated plots were recorded in 1940, with average gains of 692, 542, and 375 pounds of seed cotton per acre for the 4-, 6-, and 8-day-interval treatments, respectively. Although the increased yields were high in 1939, 1940, and 1941, they were rather low during the 8-year period, in which the average increased yields were 208, 143, and 100 pounds of seed cotton per acre for the 4-, 6-, and 8-day-interval treatments.

The average yearly yield per acre obtained from plots dusted at 4-day intervals was significantly larger than that from plots dusted at either 6- or 8-day intervals.

SUMMARY.—Experiments comparing applications of calcium arsenate for boll weevil control at different times of the day and at different intervals between applications, conducted near Tallulah, La., from 1934 to 1941, inclusive, are reported. In the time-of-day series, applications of calcium arsenate dust were made during the early morning, near midday, and in the late afternoon, and in the time-interval series during the early morning at 4-, 6-, and 8-day intervals. During 1934, 1935, 1938, 1939, 1940, and 1941 applications of calcium arsenate applied during the early morning gave an average increase over the checks of 309 pounds of seed cotton per acre, those near mid-day 311 pounds, and those during the late afternoon 264 pounds. From 1934 to 1941, inclusive, applications of calcium arsenate made at 4-day intervals gave an average increase over the checks of 208 pounds of seed cotton per acre, those at 6-day intervals 143 pounds, and those at 8-day intervals 100 pounds.—2-11-42.

LITERATURE CITED

Young, M. T., G. L. Garrison and R. C. Gaines. 1940. Insecticides for boll weevil control. JOUR. ECON. ENT. **33**(5): 787–92.

MAJOR H. N. WORTHLEY

Dr. Harlan N. Worthley of the Pennsylvania Agricultural Experiment Station, State College, has accepted a commission as a Major in the Chemical Warfare Service. He is now located at the Replacement Training Center, Gadsden, Alabama.

MAJOR LOUIS A. STEARNS

Dr. Louis A. Stearns, Entomologist and Professor of Entomology at the University of Delaware, Newark, has accepted a commission as a Major in the United States Army and has reported for duty at the Walter Reed Hospital, Washington, D. C.

Calcium Arsenate With and Without Aphicides for Control of Boll Weevil and Cotton Aphid

M. T. Young, G. L. Garrison, and R. C. Gaines, *U. S. Department of Agriculture, Bureau of Entomology and Plant Quarantine*[1]

In experiments against the boll weevil, *Anthonomus grandis* Boh., and the cotton aphid, *Aphis gossypii* Glov., at Tallulah, La., in 1941, calcium arsenate was combined with aphicides in various concentrations and applied at different times of day and frequency intervals. Zinc-safened calcium arsenate, mixtures of calcium arsenate with derris, cube, and timbo as sources of rotenone, and mixtures of calcium arsenate with nicotine sulfate and free nicotine were compared with calcium arsenate and untreated checks.

The same brand of calcium arsenate was used in all treatments. It contained on an average 41.7 per cent of total arsenic pentoxide, 9.1 per cent of water-soluble arsenic (New York method), and 11.9 per cent of free lime. The zinc-safened calcium arsenate contained on an average 42.7 per cent of total arsenic pentoxide, 0.40 per cent of water-soluble arsenic (New York method), and 3.4 per cent of zinc oxide and had a pH of 10.5. The derris contained 4.9 per cent of rotenone and 15.8 per cent of total extractives; the cube, 5.2 per cent of rotenone and 22.3 per cent of rotal extractives; the timbo, 6.0 per cent of rotenone and 22.3 per cent of total extractives. Each of these rotenone-bearing products was added to the calcium arsenate in a proportion to make 0.5 per cent of rotenone in the final mixture. Nicotine sulfate solution containing 40 per cent of nicotine was mixed with calcium arsenate to make 0.5, 1, and 2 per cent of nicotine in the mixtures. The calcium arsenate-free nicotine mixture was prepared from a dust containing 10 per cent of free nicotine so that the final mixture contained 1 per cent of free nicotine.

The plots were 22 rows wide and of sufficient length to contain one-fourth acre or more. Boll weevil and aphid infestation records were made on the 12 center rows, or one-tenth acre of each plot. Yield records were made on one-thirtieth acre in the center of the plot. The treatments were assigned to the plots at random in a block, and a block consisted of as many plots as there were treatments.

Weevil infestation records were made by examining 200 squares in each plot. On the first record approximately one-third of the squares were taken near the end of the first and second rows to the right of the center, one-third near the middle on the third and fourth rows to the right of the center, and the remainder near the opposite end of the fifth and sixth rows from the right of the center. On the next record counts were made in the same manner but to the left of the center. Approximately the same points were used every 2 weeks. The average square infestation when the treatments were begun ranged from 18 to 28 per cent. Aphid-infestation records were made in the same locations as the square-infestation records by counting the aphids on 1 square inch of leaf surface near the center on the underside of the fourth leaf from the top of the plant. At the beginning of the season counts were made on 100 leaves, but as the aphids became more numerous it became necessary to reduce this number to 30 and finally to 10 leaves per plot. Aphid records were made at approximately weekly intervals. The yield record given is the average yield per acre.

An accurate record was made of the quantity of insecticide applied to each plot by weighing the single-nozzle rotary hand dust gun before an application was begun and again after it was completed. In experiment 1, 9 applications, 8 of which were effective, were made from July 14 to August 18 at either 4- or 5-day intervals in the early morning. An average of 5.7 to 7.1 pounds of insecticide was used per acre per application. In experiment 2, 7 applications, 6 of which were effective, were made from July 12 to August 9 at either 4- or 5-day intervals. Blocks 1 and 2 received an additional effective application on August 14. The applications on the E plots were made in the late afternoon and those on the B, C, and D plots in the early

[1] The authors were assisted in the field by T. F. Henderson, G. H. Rainwater, W. A. Lee, and R. R. Coffin. All chemical analyses of insecticides reported in this paper were made by the Division of Insecticide Investigations, of the Bureau of Entomology and Plant Quarantine.

Table 1.—Boll weevil and cotton aphid infestations and cotton yields, following various insecticide treatments together with analysis of variance.

Treatment	Boll Weevil—Punctured Squares		Aphids per Square Inch, Number	Yield of Cotton per Acre, Pounds	Analysis of Variance				
						Degrees of Freedom	Mean Square		
	Per Cent	Angle			Source of Variation		Boll Weevil (Angle)	Aphid	Yield 1/30 Acre
Experiment 1, early morning applications:									
A—Check	43	40.8	24	1,071					
B—Calcium arsenate	27	31.6	47	1,074					
C—Calcium arsenate and derris, 0.5% rotenone	27	31.2	28	1,284	Experiment 1:				
D—Calcium arsenate and cube, 0.5% rotenone	22	28.0	28	1,299	Blocks	5	356.11	178.61	8.11
E—Calcium arsenate and timbo, 0.5% rotenone	23	28.6	26	1,380	Treatments	5	128.08[1]	429.66[2]	120.25[2]
F—Zinc-safened calcium arsenate	29	32.7	35	1,110	Error	25	33.57	29.31	7.35
Minimum significant difference:									
5% level		6.9	6	96					
1% level		9.3	9	132					
Experiment 2, morning and afternoon applications:									
A—Check	64	52.9	22	972					
B—Calcium arsenate, early morning	38	38.2	41	1,008	Experiment 2:				
C—Calcium arsenate and cube, 0.5% rotenone, early morning	36	37.1	24	1,200	Blocks	4	181.75	563.38	7.86
D—Calcium arsenate and nicotine sulfate, 0.5% nicotine, early morning	34	35.5	33	1,062	Treatments	4	244.91[2]	415.70[2]	73.66[1]
E—Calcium arsenate and nicotine sulfate, 0.5% nicotine, late afternoon	40	39.3	19	1,230	Error	16	23.98	54.39	20.01
Minimum significant difference:									
5% level		6.6	10	180					
1% level		9.0	14	249					
Experiment 3, late afternoon applications:									
A—Check	61	51.5	17	642					
B—Calcium arsenate	36	36.9	36	1,026					
C—Calcium arsenate and cube, 0.5% rotenone	35	36.0	21	1,212	Experiment 3:				
D—Calcium arsenate and nicotine sulfate, 1% nicotine	37	37.3	9	1,488	Blocks	4	32.39	23.41	11.66
E—Calcium arsenate and free nicotine, 1% nicotine	32	34.2	15	1,230	Treatments	4	243.12[2]	530.78[2]	546.26[2]
Minimum significant difference:					Error	16	12.34	84.24	40.61
5% level		4.7	12	255					
1% level		6.5	17	354					
Experiment 4, late afternoon applications:									
A—Check	53	46.5	17	804					
B—Calcium arsenate	32	34.2	38	1,014					
C—Calcium arsenate and nicotine sulfate, 0.5 nicotine	26	30.8	17	1,269	Experiment 4:				
D—Alternate applications of calcium arsenate and a mixture of calcium arsenate and nicotine sulfate, 1% nicotine	29	32.4	12	1,410	Blocks	3	34.92	4.17	19.25
E—Alternate applications of calcium arsenate and a mixture of calcium arsenate and nicotine sulfate, 2% nicotine	26	30.9	3	1,485	Treatments	4	172.57[2]	637.06[2]	358.83[2]
Minimum significant difference:					Error	12	13.79	15.46	22.13
5% level		5.7	6	216					
1% level		8.0	8	306					

[1] Significant.
[2] Highly significant.

morning. An average of 6.8 to 8.0 pounds of insecticide was used per acre per application. In experiment 3, 10 applications, 7 of which were effective, were made from July 7 to August 14, and an average of 5.9 to 6.4 pounds of insecticide was used per acre per application. In experiment 4, 9 applications, 6 of which were effective, were made from July 7 to August 9, and the average quantity of insecticide per acre per application ranged from 5.9 to 7.0 pounds. In experiments 3 and 4 treatment was made during the late afternoon from 5:30 to 7:30 P.M. at 5-day intervals. Whenever an insecticide was washed off within 24 hours after being put on, the application was considered ineffective and another was made as soon as possible.

After treatment was begun, sampling data on infestations, recorded as percentages of squares punctured by boll weevils, were obtained. The percentages were transformed to equivalent angles for use in the analysis of variance, and the percentages given are those corresponding to the mean angles. The aphid infestation records are the average numbers of aphids per square inch. In both weevil and aphid infestation records only those made after treatment was begun are included in the means. These data and those on yields were statistically analyzed, and are given

in table 1, together with the minimum significant differences between means required at the 5-per cent and the 1-per cent levels.

EXPERIMENT 1.—Calcium arsenate, each of the three mixtures containing rotenone, and zinc-safened calcium arsenate applied in the early morning were equally effective for boll weevil control. Each of the three mixtures containing rotenone gave a significant reduction in number of aphids and a significant increase in yield as compared with calcium arsenate and zinc-safened calcium arsenate. Calcium arsenate and zinc-safened calcium arsenate failed to give significant increases in yield over the checks, but each of the three mixtures containing rotenone gave a significant increase.

EXPERIMENT 2.—The insecticides were equally effective against the boll weevil and each gave significant boll weevil control over the checks. Fewer aphids were found following late-afternoon applications of the mixture containing nicotine sulfate than following either early-morning applications of the mixture containing rotenone or early-morning applications of the mixture containing nicotine sulfate. Late-afternoon applications of the mixture containing nicotine sulfate and early-morning applications of the mixture containing rotenone were each followed by a significant increase in yield over the checks and early-morning applications of calcium arsenate alone.

EXPERIMENT 3.—The insecticides were equally effective against the boll weevil and each was followed by significant boll weevil control over the checks. Late-afternoon applications of the mixture of calcium arsenate and nicotine sulfate gave better control of cotton aphids than the mixture containing rotenone or the mixture of calcium arsenate and free nicotine. All the treatments were followed by significant increases in yield over the checks. The mixture of calcium arsenate and nicotine sulfate gave a significantly better yield than calcium arsenate alone, the mixture containing rotenone, or the mixture of calcium arsenate and free nicotine.

EXPERIMENT 4.—The insecticides were equally effective against the boll weevil and each was followed by significant boll weevil control over the checks. Late-afternoon alternate applications of calcium arsenate alone and the mixture containing 2 per cent of nicotine were followed by much greater reductions in aphid numbers than alternate applications of calcium arsenate alone and the mixture containing 1 per cent of nicotine or the mixture containing 0.5 per cent of nicotine. Each of the mixtures containing nicotine was followed by a significant increase in yield over the checks and calcium arsenate alone. Alternate applications of calcium arsenate alone and the mixture containing 2 per cent of nicotine were followed by a significant increase in yield over the mixture containing 0.5 per cent of nicotine and an increase in yield over alternate applications of calcium arsenate alone and the mixture containing 1 per cent of nicotine.

SUMMARY.—In tests against the boll weevil and cotton aphid conducted near Tallulah, La., in 1941, calcium arsenate, zinc-safened calcium arsenate, mixtures of calcium arsenate containing 0.5 per cent of rotenone, and mixtures of calcium arsenate containing 0.5, 1, and 2 per cent of nicotine were equally effective against the boll weevil, and each was followed by significant boll weevil control over the checks. Zinc-safened calcium arsenate did not prevent the aphid infestation from increasing to injurious numbers. The calcium arsenate and rotenone mixtures, made from derris, cube, or timbo, were equally effective against the cotton aphid and gave highly significant decreases in aphid infestation and increases in yield when compared with calcium arsenate alone. A mixture of calcium arsenate and 0.5 per cent of nicotine applied in the late afternoon gave better aphid control and a greater yield than either a similar mixture or a mixture of calcium arsenate and rotenone applied in the early morning. Mixtures of calcium arsenate and nicotine gave better aphid control and a greater yield than a mixture of calcium arsenate and rotenone. Dust made with nicotine sulfate was more effective in controlling aphids than that made with free nicotine. Alternate applications of calcium arsenate and a mixture of calcium arsenate and 2 per cent of nicotine were much more effective in controlling aphids and gave greater yields than alternate applications of calcium arsenate and a mixture of calcium arsenate and 1 per cent of nicotine or a mixture of calcium arsenate and 0.5 per cent of nicotine.—2-10-42.

Effect of Boll Weevil and Cotton Aphid Control on Yield as Shown in a Factorial Experiment in 1941

R. C. Gaines, *U. S. Department of Agriculture, Bureau of Entomology and Plant Quarantine*[1]

Experiments employing factorial designs were conducted in 1941 at Florence, S. C., Gainesville, Fla., Tallulah, La., and College Station, Tex., to determine the comparative effect on infestation and cotton yield of treatment with calcium arsenate dust for control of the boll weevil, *Anthonomus grandis* Boh., and either nicotine dust or spray for control of the cotton aphid, *Aphis gossypii* Glov., and a combination of the two treatments. The experiment at College Station was made by the Texas Agricultural Experiment Station. Similar experiments were made in 1939 at Tallulah and in 1940 at Florence, Tallulah, College Station, and Waco, Tex. (Gaines *et al.* 1940; Gaines 1941).

Plots and Treatments.—The plots varied somewhat in size at the four localities. At Florence each plot had a total area of one-eighteenth acre, at Gainesville one-twentieth acre, at Tallulah one-fourth acre, and at College Station one-eighth acre. Insecticide applications were made over the entire plot, but yield records were made within the surrounding buffers, on one-fiftieth acre at Florence and Gainesville, one-thirtieth acre in experiment 1, one-twenty-fifth acre in experiment 2 at Tallulah, and one-eighteenth acre at College Station. The plots, to which treatments were assigned at random, were arranged in blocks. There were four replicate blocks at Florence, Gainesville, and College Station. At Tallulah there were four replicate blocks in experiment 1 and two in experiment 2.

Treatment A was the check, treatment B was calcium arsenate dust for control of the boll weevil, treatment C was nicotine, either dust or spray, for control of the cotton aphid, and treatment D was both calcium arsenate and nicotine for control of the boll weevil and the cotton aphid.

The same brand of calcium arsenate was used at all localities. At Gainesville a nicotine spray was used which was prepared by adding to each 100 gallons of water approximately 2 pounds of 40-per cent nicotine sulfate. At the other localities a dust mixture was used which consisted of 90 parts of tobacco dust and 10 parts of lime, to which was added 6 pints of 40-per cent nicotine sulfate. The mixture contained approximately 3 per cent of nicotine.

The method of making treatment applications and records has been discussed by the writer (Gaines 1941).

Results.—Boll weevil and aphid infestations and cotton yields following the different treatments in various localities, together with analysis of variance, are given in table 1. The percentages of squares punctured by boll weevils were transformed to equivalent angles for use in the analyses of variance. The percentages given in the table are those corresponding to mean angles.

In each of the three sets of analyses for the combined records for all localities the treatment-locality interaction was highly significant, an indication, as in 1940, that the differential response to treatments at the various localities may be attributed to the combination of infestations that prevailed during the course of each experiment. At Florence there was a heavy boll weevil infestation and an extremely light aphid infestation. At Gainesville there was a very light infestation of weevils but a heavy aphid infestation when calcium arsenate was used. At Tallulah there was a heavy infestation of both weevils and aphids, and at College Station the boll weevil infestation was intermediate and the aphid infestation light.

Calcium arsenate (B and D vs. A and C) gave significant reductions in boll weevil infestations at all localities, significant increases in aphid numbers at all localities except Tallulah (Experiment 2) and significant increases in yield at all localities except Gainesville and Tallulah (Experiment 2). The increase in yield at College Station was in part due to the control of bollworms. Nicotine (C and D vs. A and B) gave significant reductions in aphid numbers at all localities except Tallulah (Experiment 2) and significant increases

[1] Records at Florence, S. C., were made by F. F. Bondy, C. F. Rainwater, R. L. Walker, Minter Dupree, and C. S. Gardiner, Jr.; at Gainesville, Fla., by C. S. Rude, E. H. Reese, Jr., S. W. Walkup, A. D. Taylor, and G. T. Edwards; at Tallulah, La., by M. T. Young, G. L. Garrison, G. H. Rainwater, W. A. Lee, T. F. Henderson, and R. R. Coffin; and at College Station, Tex., by J. C. Gaines, H. A. Dean, E. W. Jackson, and D. C. Thurman.

Table 1.—Boll weevil and cotton aphid infestations and cotton yields, following three insecticidal treatments at four localities, together with analyses of variance.

Locality and Treatment	Boll Weevil—Punctured Squares		No. of Aphids per Square Inch of Leaf Area	Pounds of Seed Cotton per Acre
	Per Cent	Angle		
Florence, S. C.:				
(A) Check	52	46.0	2.10	116
(B) Calcium arsenate	25	30.0	9.01	570
(C) Nicotine dust	54	47.3	.95	99
(D) Calcium arsenate and nicotine dust	21	27.4	4.82	601
Minimum significant difference:				
5% level		5.1	.91	131
1% level		7.3	1.31	188
Gainesville, Fla.:				
(A) Check	7	14.8	6.97	685
(B) Calcium arsenate	4	11.2	43.80	508
(C) Nicotine spray	5	13.3	.31	852
(D) Calcium arsenate and nicotine spray	4	11.1	1.77	904
Minimum significant difference:				
5% level		2.7	13.11	229
1% level		3.9	18.84	329
Tallulah, La., Experiment 1:				
(A) Check	53	46.5	9.00	675
(B) Calcium arsenate	30	33.4	25.84	1,110
(C) Nicotine dust	55	48.0	1.32	780
(D) Calcium arsenate and nicotine dust	30	33.4	4.17	1,538
Minimum significant difference:				
5% level		4.3	7.45	271
1% level		6.2	10.70	390
Tallulah, La., Experiment 2:				
(A) Check	42	40.2	8.95	1,163
(B) Calcium arsenate	22	28.1	27.61	963
(C) Nicotine dust	36	36.8	.65	1,100
(D) Calcium arsenate and nicotine dust	19	25.5	2.62	1,575
Minimum significant difference:				
5% level		9.7	—	—
1% level		17.7	—	—
College Station, Tex.:				
(A) Check	33	35.0	4.11	950
(B) Calcium arsenate	16	23.7	8.97	1,378
(C) Nicotine dust	38	37.9	1.93	1,040
(D) Calcium arsenate and nicotine dust	19	25.8	3.74	1,344
Minimum significant difference:				
5% level		3.4	1.72	263
1% level		4.9	2.47	378
All localities:				
(A) Check	35	36.1	5.92	668
(B) Calcium arsenate	18	25.0	22.54	900
(C) Either nicotine dust or spray	36	36.6	1.07	738
(D) Calcium arsenate and either nicotine dust or spray	17	24.5	3.51	1,150

Analysis of Variance				
Source of Variation	Degrees of Freedom	Mean Square: Boll Weevil (Angle)	Mean Square: Aphid	Mean Square: Yield
Florence, S. C.:				
Blocks	3	37.56	1.93	4,968.23
Treatments:				
A & C vs. B & D	1	1,281.64[2]	116.10[2]	914,414.06[2]
A & B vs. C & D	1	1.69	28.46[2]	189.06
A & D vs. B & C	1	15.21	9.30[2]	2,376.56
Total	3	432.85[2]	51.29[2]	305,659.90[2]
Error	9	10.07	.32	6,661.28
Gainesville, Fla.:				
Blocks	3	14.25	142.92	57,269.67
Treatments:				
A & C vs. B & D	1	33.06[2]	1,466.51[2]	15,625.00
A & B vs. C & D	1	2.40	2,370.72[2]	315,844.00[2]
A & D vs. B & C	1	2.25	1,251.74[2]	52,441.00
Total	3	12.57[1]	1,696.32[2]	127,970.00[1]
Error	9	2.92	67.21	20,535.11
Tallulah, La., Experiment 1:				
Blocks	3	4.23	35.92	98,906.25
Treatments:				
A & C vs. B & D	1	765.91[2]	387.89[2]	1,422,056.25[2]
A & B vs. C & D	1	2.33	861.72[2]	283,556.25[1]
A & D vs. B & C	1	2.33	195.44[1]	104,006.25
Total	3	256.85[2]	481.68[2]	603,206.25[2]
Error	9	7.18	21.68	28,806.25
Tallulah, La., Experiment 2:				
Blocks	1	21.45	90.79	11,250.00
Treatments:				
A & C vs. B & D	1	274.95[1]	212.70	37,812.50
A & B vs. C & D	1	18.30	553.95	151,250.00
A & D vs. B & C	1	.28	139.36	227,812.50[1]
Total	3	97.85[1]	302.00	138,958.33
Error	3	9.20	61.13	16,041.67
College Station, Tex.:				
Blocks	3	20.97	3.52	4,319.56
Treatments:				
A & C vs. B & D	1	549.90[2]	44.56[2]	537,655.57[2]
A & B vs. C & D	1	24.50[1]	54.91[2]	3,164.06
A & D vs. B & C	1	.72	9.27[1]	15,314.06
Total	3	191.71[2]	36.25[2]	185,377.90[1]
Error	9	4.64	1.16	27,017.40
All localities:				
Treatments	3	808.82	1,701.18	823,176.78
Localities	4	1,885.91	233.50	1,860,051.87
Treatments ×localities	12	45.75[2]	216.59[2]	134,498.90[2]
Blocks within localities	13	19.42	49.51	39,049.32
Treatments ×blocks within localities	39	6.43	25.56	20,392.45

[1] Significant.
[2] Highly significant.

in yield at Gainesville and Tallulah (Experiment 1), but did not significantly affect boll weevil infestations at any locality except College Station. Calcium arsenate and nicotine (A and D vs. B and C) interacted to cause significant reductions in aphid numbers at Florence, Gainesville, Tallulah (Experiment 1), and College Station and to give a significant increase in yield at Tallulah (Experiment 2).

Calcium arsenate (A vs. B) gave significant increases in yield at Florence of 454 pounds of seed cotton per acre (391 per cent) and at Tallulah (Experiment 1) of 435 pounds (64 per cent), where weevil infestations were heavy, and at College Station 428 pounds (45 per cent), where weevil infestation was intermediate. Nicotine (A vs. C) gave non-significant increases in yield at Gainesville of 167

pounds (24 per cent), at Tallulah (Experiment 1) 105 pounds (16 per cent), and at College Station 90 pounds (9 per cent). Both calcium arsenate and nicotine (A vs. D) gave significant increases in yield over the checks at Florence of 485 pounds (418 per cent), at Tallulah (Experiment 1) 863 pounds (128 per cent), and College Station 394 pounds (41 per cent), and increases in yield that were not significant at Gainesville of 219 pounds (32 per cent) and at Tallulah (Experiment 2) of 412 pounds (35 per cent). Calcium arsenate and nicotine gave significant increases in yield over calcium arsenate alone (B vs. D) at Gainesville of 396 pounds (78 per cent) and at Tallulah (Experiment 1) of 428 pounds (39 per cent), and apparent increases that were not significant at Florence of 31 pounds (5 per cent) and at Tallulah (Experiment 2) of 612 pounds (64 per cent). There was a loss of 34 pounds, or 2 per cent, at College Station, but in the plots treated with calcium arsenate plus nicotine at that locality the average boll weevil infestation was 3 per cent higher than in the plots treated with calcium arsenate.—2-11-42.

LITERATURE CITED

Gaines, R. C., M. T. Young and G. L. Smith. 1940. Effect of insecticides used in boll weevil control upon aphids and mirids. JOUR. ECON. ENT. **33**(5): 792–6.

Gaines, R. C. 1941. Effect of boll weevil control and cotton aphid control on yield as shown in a factorial experiment. JOUR. ECON. ENT. **34**(4): 501–4.

Boll Weevil Hibernation, Survival, and Emergence Under South Carolina Conditions

FLOYD F. BONDY and C. F. RAINWATER, *U. S. Department of Agriculture, Bureau of Entomology and Plant Quarantine*

In connection with investigations on the control of the boll weevil, *Anthonomus grandis* Boh., studies have been made of the factors that influence the insect's abundance with particular reference to hibernation, survival, and emergence. These studies were made in the vicinity of Florence, S. C., and include cage tests, examinations of Spanish moss and woods trash, and trap-crop emergence records. The results herein reported supplement those of Fenton & Dunnam (1929).

CAGE TESTS.—The cage tests cover a 10-year period, from the fall of 1931 to the spring of 1941. The purpose of these tests was (1) to obtain a comparative index of survival from year to year under various climatic conditions in different types of hibernating shelter and (2) to determine the effect on survival of removing the weevils from food and placing them in hibernation at definite intervals before frost kills the plants in the fall.

The cages used were 4 by 4 by 4 foot wooden frames covered with 16-mesh screen; they had open bottoms and rested on a smooth soil surface. A 2-foot door in one side permitted the placing of hibernation material and the installation and removal of the weevils. Some of these cages were put in an open field and others in the woods.

The shelter materials used were (1) Spanish moss suspended in festoons from two cross wires placed about 1 foot from the top of the cage, (2) cornstalks cut into approximately 3-foot lengths and stacked vertically in the cage, and (3) surface woods trash placed in the cages to a depth of about 6 inches.

Installation of the weevils was made each year on October 15, November 1, and November 15 by releasing 500 field-collected weevils in good condition in each cage. There was but one date of installation, November 1, for the woods cages. An attempt was made to install an equal number of field cages for each of the above installation dates but in some years early freezes killed the cotton and made it difficult to collect sufficient weevils for the November 15 installation. Ten cages were installed in the woods each year, whereas the number of cages located in the open fields ranged from 45 to 60 per year.

The number of weevils that survived the winter in these cages varied slightly for the different hibernation materials

Table 1.—Results of cage experiments on boll weevil hibernation. Pee Dee Experiment Station.

Year	Lowest Temperature, Degrees F.	Daily Average Weevils Active on Walls; April	October 15 Installation		November 1 Installation[1]		November 15 Installation	
			Number	Per Cent Survival	Number	Per Cent Survival	Number	Per Cent Survival
1931–32	22	54	10,000	5.21	15,000	4.79	10,000	1.47
1932–33	19	112	10,000	4.67	15,000	9.91	10,000	5.23
1933–34	8	8	10,000	.01	15,000	.02	8,000	.075
1934–35	14	30	10,000	.40	15,000	.87	4,000	.90
1935–36	2	0.4	10,000	.00	15,000	.001	5,000	.02
1936–37	23	70	10,000	2.17	15,000	5.21	5,000	10.22
1937–38	17	43	10,000	.81	15,000	.93	9,000	.456
1938–39	22	73	10,000	1.61	15,000	2.91	10,000	2.92
1939–40	13	0.8	10,000	.04	15,000	.04	5,000	.12
1940–41	23	139	7,500	.77	12,500	11.91	7,500	16.08
Total	—	—	97,500	—	147,500	—	73,500	—
Average	—	—	—	1.57	—	3.66	—	3.75

[1] Includes cages in open field and woods.

used. There was consistently higher survival in woods trash than in either Spanish moss or cornstalks and more survival in Spanish moss than in cornstalks. Also the survival from woods cages was greater than from open-field cages. Because of the slight variation in survival from the different kinds of hibernation material used, the results have been combined for each date of installation (Table 1).

It will be noted that only a small percentage of weevils survived even the mildest winters and that temperature was the most important factor influencing survival. For the 4 years when the minimum temperature was below 15 degrees F. the average survival was 0.21 per cent as compared with 5.67 per cent for the 5 years when the minimum temperature was 19 degrees or above.

It is also interesting to note the extremes in survival that occurred during the different years for the different dates of installation. The average survival for the November 15 installation was more than twice that for the October 15 installation, whereas the 1941 survival was more than twenty times as great. These data show the practical value of the early fall destruction of cotton stalks so as to remove the food from the weevils and force them into hibernation early and in a weakened condition.

Table 2.—Hibernation and survival of boll weevils in Spanish moss.

Year	Lowest Minimum Temp.	Weevils per Ton of Moss Fall		Spring	
		Total Number	Per Cent Alive	Total Number	Per Cent Alive
1928–29	23°F	779	98.6	101	70.2
1929–30	15	829	26.8	210	12.9
1930–31	20	485	97.9	65	38.5
1931–32	22	177	97.2	107	90.7
1932–33	19	340	100.0	46	71.7
1933–34	8	98	79.6	56	7.1
1934–35	14	349	84.5	88	4.5
1935–36	2	559	27.4	97	.0
1936–37	23	249	40.6	160	40.7
1937–38	17	1,080	83.7	56	8.9

EXAMINATION OF SPANISH MOSS.—From the fall of 1928 to the spring of 1938 regular examinations of Spanish moss were made during the fall to determine the relative number of boll weevils that hibernated in this material and again in the spring to determine the per cent that survived the winter. These examinations were made by collecting moss hanging from the limbs of trees near cotton fields and carefully tearing the moss apart over a table covered with a white cloth so that boll weevils and other insects were dislodged and could be easily seen. The results of these examinations are given in table 2.

Table 2 shows that temperature was an important factor in weevil survival in the spring. It also shows that comparatively large numbers of weevils hibernated in Spanish moss when this material was adjacent to cotton fields. Many farmers have learned this, and therefore cotton fields are seldom found close to trees heavily loaded with Spanish moss in South Carolina. The scarcity of such fields forced a discontinuance of these examinations, and since the spring of 1938 comparative records on boll weevil hibernation have been made by examining surface woods trash.

EXAMINATION OF SURFACE WOODS TRASH.—Systematic examinations to determine the number of boll weevils hibernating in surface woods trash and the distance weevils enter the woods for hibernation were begun in the winter of 1937–38. Samples of surface trash, consisting of twigs, leafage, and other forest debris mixed with soil, were carefully raked up from 3 by 6 foot areas at different distances into the woods from the edge of the cotton fields. The trash material, after storage in a warm place to dry somewhat and permit the weevils to become active, was run through a special shaker machine, which eliminated material larger and smaller than boll weevils. The portion of trash between these extremes was then carefully examined over a white-topped table. The results are shown in table 3.

These examinations showed that 78 per cent of the total number of boll weevils found were within 50 feet of the edges of the woods bordering cotton fields and that practically none were found at distances greater than 150 feet from the edges. This information indicates the futility of burning large areas of woods for weevil control. Numerous insects other than boll weevils were found (Rainwater 1941).

By making examinations of woods trash over a period of years and correlating the results with prevailing seasonal weather conditions, it is believed that a more reliable index of probable boll weevil abundance will be secured than was formerly obtained from examinations of Spanish moss. Records from woods trash also serve as a check on the cage hibernation records, and the data obtained from these two sources are of value to farmers in planning to have insecticides and dusting machines on hand when needed.

Table 3.—Hibernation of boll weevils in woods trash.

Year	Lowest Minimum Temp. Degrees F.	Square Feet of Surface Area Examined	Number of Live Weevils Found	Number of Live Weevils per Acre
1937–38	17°F.	2,160	73	1,472
1938–39	22	1,800	148	3,582
1939–40	13	990	4	176
1940–41	23	1,800	81	1,960

EMERGENCE RECORDS FROM TRAP-CROP PLANTING.—Although the records from hibernation cages and woods-trash examinations serve as a fairly reliable index of boll weevil survival and abundance in comparison with previous years, they do not show when weevils will emerge from hibernation and return to cotton fields under natural conditions. Emergence in cages, and especially in those in the open field, was found to occur considerably earlier than emergence from natural hibernation quarters.

Table 4.—Boll weevil emergence by 15-day intervals from one-fifth acre trap-crop planting of cotton.

Period of Emergence	Number of Weevils Removed					Per Cent of Total Emergence
	1938	1939	1940	1941	Total	
April 15–30	31	0	0	0	31	1.36
May 1–14	50	0	0	0	50	2.18
May 15–31	59	87	3	33	182	7.94
June 1–14	140	212	31	592	975	42.56
June 15–30	100	442	21	490	1,053	45.96
Total	380	741	55	1,115	2,291	100.00

A study of the period when weevils emerged from natural hibernation and entered the cotton fields was begun in 1938 on an isolated trap plot of early planted cotton. This planting has been continued each year since on the same $\frac{1}{5}$ acre area. Each plant was examined at least three times weekly from the time that the cotton was large enough for weevils to feed on until July 1. Every boll weevil found was counted and killed and every square that formed on these plants during this period was removed so that no new weevils could develop. The results are shown in table 4.

The figures in table 4 show that in nature approximately 88 per cent of the total boll weevil emergence occurs in June and that approximately 46 per cent of the total emergence occurs between June 15 and June 30. They also help explain why presquare poisoning is ineffective in certain years and why it can never be relied upon to give adequate control in years of heavy emergence.

Ordinarily in the vicinity of Florence cotton is fruiting rapidly and squares are available for food by June 15. Mopping the cotton with sweetened poison is not effective in controlling boll weevils after squares are large enough for the insects to feed upon. Since such a large emergence occurs after squares are present, it is obvious why this method of control fails to give the expected results.—3-11-42.

LITERATURE CITED

Fenton, F. A., and E. W. Dunnam. 1929. Biology of the cotton boll weevil at Florence, S. C. U. S. Dept. Agr. Tech. Bul. 112.

Rainwater, C. F. 1941. Insects and spiders found in Spanish moss, gin trash, and woods trash, and on wild cotton. U. S. Dept. Agr., Bur. Ent. and Plant Quar. E-528.

Mopping, Dusting, and Combination Treatments for Boll Weevil Control in South Carolina

FLOYD F. BONDY, *U. S. Department of Agriculture, Bureau of Entomology and Plant Quarantine*

The active interest in South Carolina in the use of "sweetened poison," or a mixture of calcium arsenate, molasses, and water, applied by "mopping" for control of the boll weevil, *Anthonomus grandis* Boh., has made it necessary to conduct experiments over a period of years to determine fully the effectiveness of this method as compared with dusting with calcium arsenate and a combination of mopping and dusting. The use of the mopping method has been stimulated by economic conditions in South Carolina and the fact that certain light, sandy soils of that state are subject to injury from the use of large quantities of calcium arsenate and that aphid injury often occurs following applications of that insecticide.

EXPERIMENTAL METHODS.—The mopping mixture used was prepared by thoroughly mixing 1 gallon of blackstrap molasses, 1 gallon of water, and 1 pound of calcium arsenate. This mixture is known as the 1-1-1 mopping mixture. It is applied to the cotton in the pre-square stage with hand mops made by tying pieces of burlap to the end of a board 2 to 3 feet long and about 3 inches wide at the end, and shaped to fit the hand. The mop is dipped into a bucket of the mixture and held so that a small amount of the sweetened poison is smeared on the tops of the plants as the operator moves forward. From one to three applications, each at the rate of approximately 2 gallons per acre, were made before the squares were large enough for the boll weevils to puncture them. The calcium arsenate dust was applied to the cotton with rotary hand-dusting machines at night or early in the morning, when the plants were moist with dew, beginning when approximately 10 per cent of the squares had been punctured. The combination treatment consisted of the regular mopping applications followed by dusting with calcium arsenate

Table 1.—Comparative increases in cotton yield and net profit or loss per acre following mopping, dusting, and combined mopping and dusting for boll weevil control.

Year	Number of Tests	Pounds Seed Cotton per Acre: Untreated Check	Pounds Seed Cotton per Acre: Increase	Cost of Treatment per Acre	Net Profit or Loss per Acre
MOPPING					
1928	13	413	50	$1.20	$3.40
1929	13	612	155	1.73	9.45
1930	4	1,163	24	1.28	−.02
1931	3	1,090	−18	1.28	−1.28
1932	0	—	—	—	—
1933	6	1,209	20	.79	−.05
1934	6	1,314	63	.95	1.79
1935	8	1,338	28	1.31	−.19
1936	13	1,529	18	1.23	−.14
1937	3	975	66	1.20	.57
1938	2	855	22	1.30	−.60
1939	2	1,740	19	1.42	1.01
1940	0	—	—	—	—
1941	5	379	23	1.35	−.75
Total	78	12,617	470	15.04	13.19
Average		1,051	39	1.25	1.10
Gain, Per Cent			3.7		
DUSTING					
1928	5	439	225	$5.04	$15.66
1929	11	686	482	5.02	29.57
1930	10	1,060	356	3.66	14.82
1931	7	793	320	3.88	5.78
1932	2	766	175	1.60	3.73
1933	6	804	183	2.45	4.33
1934	2	1,664	98	1.27	3.00
1935	3	843	369	5.31	9.56
1936	1	1,829	159	3.78	3.52
1937	6	1,082	80	3.78	−.42
1938	3	677	522	3.95	12.73
1939	1	899	340	4.31	6.57
1940	0	—	—	—	—
1941	3	390	413	6.12	15.99
Total	60	11,932	3,722	50.17	124.84
Average		918	286	3.86	9.60
Gain, Per Cent			31.2		
COMBINED MOPPING AND DUSTING					
1928	2	413	205	$6.10	$12.76
1929	4	495	659	5.79	41.53
1930	5	955	472	3.38	20.30
1931	10	914	282	3.30	5.25
1932	8	739	270	2.72	4.90
1933	6	894	179	2.82	3.81
1934	2	1,206	226	3.07	6.78
1935	1	932	340	5.99	7.71
1936	0	—	—	—	—
1937	5	1,128	93	4.80	−.04
1938	2	1,116	450	4.43	9.94
1939	1	1,350	298	4.48	4.86
1940	0	—	—	—	—
1941	3	390	494	7.47	18.96
Total	49	10,532	3,968	54.35	136.76
Average		878	331	4.53	11.40
Gain, Per Cent			37.7		

after 10 per cent of the squares had been punctured.

All the experiments were conducted in cooperation with farmers in Florence County, S. C. The plots for each experiment were selected for uniformity as to soil fertility, rate of fertilization, stand and variety of cotton, and seed treatment, so that the records would be comparable. The size of the plots ranged from a half acre to 1 acre. There were from 2 to 6 plots in each experiment, and in all cases an untreated check plot was left in the same field, adjacent to the treated plots. This series of experiments was begun in 1928 and continued through 1941, covering a 14-year period. No experiments on boll weevil control were conducted in 1940, owing to the scarcity of the insect in the vicinity of Florence that year.

Boll weevil infestation, cost of treatment, and yields were the most important records made. Bloom counts were made during most years, but, while these records clearly show the immediate effect of poison applications, for practical purposes they are not considered as a suitable criterion for the evaluation of the effectiveness of an insecticide. Boll counts also were made during each year but, like the bloom counts, they do not always accurately reflect the effect of the treatment on yields. Since this paper is intended to show the comparative value of the different treatments in pounds of seed cotton produced and in dollars and cents gain or loss, only these records are considered. The figures on cost of labor and materials and the value of the cotton were those prevailing each year, and therefore varied considerably from year to year.

RESULTS.—The results of these experiments are shown in table 1.

DISCUSSION.—In the 12 years that mopping alone was tested there was a monetary loss in 7 years. The average gain over this period was 39 pounds of seed cotton per acre, made at an average cost of $1.25, with an average net profit of $1.10. Dusting alone after 10 per cent infestation resulted in a monetary loss in only 1 year. The average gain from dusting alone was 286 pounds of seed cotton per acre, made at an average cost of $3.86, with a net profit of $9.60. Where both mopping and dusting were used there was a monetary loss in 1 year also. The average gain from mopping and dusting was 331 pounds of seed cotton per acre, made at an average cost of $4.53, with an average net profit of $11.40. The mopping and dusting, therefore, resulted in an average increase of 45 pounds of seed cotton over dusting alone. This additional gain attributable to mopping is about equal to the 39 pounds average gain that resulted from mopping alone.

It is felt that the period covered by these experiments is representative of climatic conditions and boll weevil abundance that might be expected over any similar period in the vicinity of Florence. The gains from mopping alone did not compare favorably with those from dusting in any year during this period. Mopping alone produced a significant increase in yield in only 1 year, when there was an increase of 155 pounds of seed cotton per acre, and in that year dusting alone resulted in an increase of 482 pounds.

SUMMARY.—A total of 187 field experiments were conducted against the boll weevil, *Anthonomus grandis*, Boh., at Florence, S. C., over the 14-year period 1928–1941 to determine the comparative value of (1) a 1-1-1 mopping mixture of calcium arsenate, molasses, and water applied to cotton in the presquare stage; (2) calcium arsenate dust applied after 10 per cent of the squares had been punctured; and (3) a combination of these two treatments. The average increases in yield over comparable untreated check plots were 39, 286, and 331 pounds of seed cotton per acre, respectively, with average net profits of $1.10, $9.60, and $11.40 per acre for the three treatments.—3-11-42.

EASTERN BRANCH TO MEET

The 1942 annual meeting of the Eastern Branch of the American Association of Economic Entomologists will be held in New York on November 19 and 20, 1942. Headquarters will be in the Hotel New Yorker.

DR. F. L. CAMPBELL IN WASHINGTON

Dr. Frank L. Campbell has taken leave of absence from the Ohio State University to perform advisory service on insecticides in the Chemicals Division, Office for Agriculture War Relations, U. S. Dept. of Agriculture, Washington, D. C.

Rotenone in Combination with Calcium Arsenate for Cotton Aphid Control

C. F. RAINWATER, *U. S. Department of Agriculture, Bureau of Entomology and Plant Quarantine*

Experiments conducted near Florence, S. C., in 1939 indicated that the addition of rotenone[1] to calcium arsenate for use in controlling the boll weevil, *Anthonomus grandis* Boh., would prevent the development of injurious infestations of the cotton aphid, *Aphis gossypii* Glov. (Bondy & Rainwater 1939, Rainwater & Bondy 1941a). These results were confirmed in experiments at Florence, S. C., State College, Miss., Tallulah, La., and Waco, Tex., in 1940 (Rainwater & Bondy 1941b). Recommendation was made by the Bureau of Entomology and Plant Quarantine, of the United States Department of Agriculture, that sufficient derris, cube, or timbo be added to the calcium arsenate to make 0.5 per cent of rotenone in the mixture (Bondy & Rainwater 1941), and considerable quantities of commercial mixtures were used by growers in 1941. In all fields observed the aphids were held in check fairly well during the dusting season, but in some fields they increased to injurious numbers between the time dusting was discontinued and the crop matured. Seasonal conditions, with frequent rains, were favorable for insect development and made control difficult.

In 1941 experiments with rotenone were conducted at Florence, S. C., Tifton, Ga., Gainesville, Fla., State College, Miss., Tallulah, La., and Waco, Tex.[2] Their purpose was to obtain additional information on (1) the effectiveness of rotenone against the aphid under different climatic and weather conditions, (2) the minimum strength of rotenone required to control the aphid, (3) the value of diluents, such as sulfur and inert materials, in the calcium arsenate-rotenone mixture, and (4) the comparative effectiveness of the rotenone-bearing materials derris, cube, and timbo.

INSECTICIDES, PLOTS, AND RECORDS.—Calcium arsenate and equal parts of calcium arsenate and sulfur were mixed with derris, cube, or timbo to make 0.1 to 0.5 per cent of rotenone in the mixture. The ground roots of these plants, containing approximately 5 per cent of rotenone, were home-mixed with the other materials. The inert materials tested as diluents were clay, talc, pyrophyllite, diatomaceous earth, and walnut-shell flour.

The plots were arranged in randomized blocks, except for one experiment at Florence in which they were arranged in a latin square. They ranged from 1/20 acre to 3 acres in size. From 4 to 8 treatments and from 1 to 6 replications of a treatment were used in each experiment. From 1 to 10 experiments, in which rotenone was used in 1 or more of the treatments, were conducted at each locality.

Three types of records were obtained for each treatment, namely, boll weevil infestations, as indicated by the percentage of squares punctured; aphid populations, as measured by the number of aphids per square inch on the fourth leaf from the top of each of 100 plants in each plot; and yields, as indicated by the average number of pounds of seed cotton per acre. Yield records were not made in the experiments conducted at State College. In this discussion the boll weevil infestation records were not taken into account, because each of the treatments used contained calcium arsenate and a statistical analysis of the data showed no significant differences between treatments. The aphid population counts are weighted seasonal averages of counts made at weekly intervals after the applications were started.

A total of 556 plots were utilized in these studies. From all experiments except those in which only one replication was made the data have been summarized and statistically analyzed by the method of analysis of variance.

Since it is obviously impractical to show the actual figures or to discuss each experiment in detail, only a general discussion of the results obtained from each locality will be given.

EXPERIMENTS AT FLORENCE.—Experiments involving 136 plots were conducted

[1] Rotenone as used in these experiments was in the form of ground roots of rotenone-bearing plants, specifically derris unless otherwise indicated.

[2] The records at Tifton, Ga., Gainesville, Fla., State College, Miss., Stoneville, Miss., Tallulah, La., and Waco, Tex., were made under the supervision of P. M. Gilmer, C. S. Rude, R. L. McGarr, E. W. Dunnam, R. C. Gaines, and K. P. Ewing, respectively.

at Florence. There were no significant differences in aphid population between the untreated check plots and the plots treated with calcium arsenate plus 0.5 per cent of rotenone and with calcium arsenate-sulfur mixture plus 0.25 per cent of rotenone, but there were highly significant differences in yield favoring the two treatments over the check. Plots treated with calcium arsenate plus 0.5 per cent of rotenone and calcium arsenate-sulfur mixture plus 0.25 per cent of rotenone had significantly less aphids than plots treated with similar mixtures plus smaller percentages of rotenone. There were significant differences in yield favoring calcium arsenate plus 0.5 per cent of rotenone over calcium-arsenate-sulfur mixture plus 0.1 per cent of rotenone and calcium arsenate alone. There was a highly significant difference in yield favoring calcium arsenate over no treatment. Treatments with 1-1 mixtures of calcium arsenate and sulfur, clay, or walnut-shell flour, plus 0.25 per cent of rotenone in each, showed no significant difference between diluents in either aphid population or yield, but each treatment caused a significantly lower aphid population than calcium arsenate alone.

EXPERIMENTS AT TALLULAH.—Experiments involving a total of 161 plots were conducted at Tallulah. There were no significant differences in aphid population between the check plots and the plots treated with calcium arsenate plus 0.5 per cent of rotenone and calcium arsenate-sulfur mixture plus 0.25 per cent of rotenone, but there was a highly significant difference in aphid population favoring plots treated with these mixtures over plots treated with calcium arsenate alone. No significant difference in aphid population occurred between plots treated with calcium arsenate alone and plots treated with calcium arsenate plus 0.1 per cent of rotenone. On the basis of both aphid population and yield there was no significant difference between derris, cube, and timbo as sources of rotenone. In five of the seven experiments cotton yields were significantly higher in plots treated with calcium arsenate plus 0.5 per cent of rotenone than in plots treated with calcium arsenate alone, and in the other two experiments they were consistently higher.

EXPERIMENT AT STONEVILLE.—An experiment involving 24 plots was conducted at Stoneville. There was a highly significant difference in aphid population favoring calcium arsenate plus 0.5 per cent of rotenone over calcium arsenate alone. The check plots had significantly fewer aphids than plots treated with calcium arsenate plus 0.5 per cent of rotenone. There was a significant difference in yield favoring calcium arsenate plus 0.5 per cent of rotenone over calcium arsenate, but there was no significant difference between this treatment and the check. A highly significant difference in both aphid population and yield occurred favoring the check plots over the plots treated with calcium arsenate and calcium arsenate-sulfur. No significant difference in either aphid population or yield was found between plots treated with calcium arsenate and those treated with calcium arsenate-sulfur. There was no significant difference in either aphid population or yield between plots treated with calcium arsenate plus 0.5 per cent of rotenone and those treated with calcium arsenate-sulfur plus 0.25 per cent of rotenone.

This experiment was conducted under conditions of apparently no boll weevil injury until very late in the season, the seasonal average weevil infestation in the check plots being only 11.05 per cent. Therefore, the difference in yield was due almost, if not entirely, to the aphid injury which resulted from the treatments. All calcium arsenate treatments except that containing rotenone resulted in a significant decrease in yield over the check.

EXPERIMENT AT GAINESVILLE.—An experiment involving 24 plots was conducted at Gainesville. No significant difference in aphid population occurred between the plots treated with calcium arsenate plus 0.5 per cent of rotenone and the untreated check plots. There was a highly significant difference in aphid population favoring calcium arsenate plus 0.5 per cent of rotenone over calcium arsenate alone and favoring calcium arsenate-sulfur over calcium arsenate. Such a difference occurred between the last two treatments in one of the experiments at Waco. No significant difference in aphid population occurred between plots treated with calcium arsenate plus 0.5 per cent of rotenone and those treated with calcium arsenate-sulfur plus 0.25 per cent of rotenone, but all such plots had significantly fewer aphids than plots treated with cal-

cium arsenate alone. There was no significant difference in yield between any two treatments, although yields in plots treated with calcium arsenate and calcium arsenate-sulfur were consistently less than yields in untreated check plots, whereas yields in plots receiving these treatments plus 0.5 and 0.25 per cent of rotenone were consistently higher than those in the check plots.

EXPERIMENT AT TIFTON.—An experiment involving 36 plots of Sea Island Cotton was conducted at Tifton. This experiment was somewhat different from those at the other stations in that only one of the treatments contained rotenone, this being calcium arsenate and 0.5 per cent of rotenone. No significant difference in aphid population occurred between the plots treated with calcium arsenate and rotenone and the check plots. There was a highly significant difference in aphid population favoring the check plots and the plots treated with calcium arsenate-rotenone over the plots receiving either calcium arsenate of zinc-safened calcium arsenate. There was a significant increase in yield (based on grams of seed cotton per plant) favoring the plots treated with calcium arsenate-rotenone over the plots treated with calcium arsenate and a highly significant difference favoring these plots over the check plots. No significant difference in yield occurred between the plots treated with calcium arsenate and the check plots.

EXPERIMENTS AT WACO.—Replicated experiments involving 32 plots and 3 field tests involving 15 plots were conducted at Waco. There was a highly significant difference in aphid population favoring calcium arsenate plus either 0.5 and 0.25 per cent of rotenone, and calcium arsenate-sulfur plus 0.5, 0.25, and 0.1 per cent of rotenone over calcium arsenate and calcium arsenate-sulfur. There was a highly significant difference in aphid population favoring calcium arsenate-sulfur over calcium arsenate alone. No significant difference in yield occurred between any of the treatments, but no check plots were included in the replicated experiments for statistical comparison. In the field tests an average of three plots showed the following: (1) Increases in yield of 44.4 and 77.8 per cent, respectively, for calcium arsenate and calcium arsenate plus 0.5 per cent of rotenone over the check plots; (2) an increase in yield of 23.2 per cent for calcium arsenate plus 0.5 per cent of rotenone over calcium arsenate alone; (3) increases in aphid population of 417.6 and 179.0 per cent, respectively, for calcium arsenate and calcium arsenate plus 0.5 per cent of rotenone over the check plots; (4) an increase in aphid population of 85.5 per cent for calcium arsenate over calcium arsenate plus 0.5 per cent of rotenone.

EXPERIMENTS AT STATE COLLEGE.—Experiments involving a total of 128 plots were conducted at State College. Because of adverse conditions, 2 of these experiments, involving 32 plots, were conducted in the vicinity of Stoneville. There were highly significant differences in aphid population favoring calcium arsenate plus 0.5 and 0.25 per cent of rotenone over calcium arsenate plus 0.1 per cent of rotenone, calcium arsenate alone, and calcium arsenate-sulfur. No significant difference in aphid population occurred between the plots treated with calcium arsenate plus 0.5 per cent of rotenone and the check plots, even though the average number of aphids was less in the treated plots. No yield records were made in any of these experiments.

SUMMARY AND CONCLUSIONS.—Experiments in which rotenone was added to calcium arsenate for control of the cotton aphid, *Aphis gossypii* Glov., were conducted at seven locations in six States during 1941. The data, which were obtained under a wide variety of conditions, showed that calcium arsenate plus 0.5 per cent of rotenone was effective in keeping the aphid population at or below that in untreated check plots and caused a significant increase in yield over plots treated with calcium arsenate alone under conditions of heavy boll weevil injury. A mixture of equal parts of calcium arsenate and sulfur plus 0.25 per cent of rotenone was not significantly different in effectiveness from calcium arsenate plus 0.5 per cent of rotenone, but the latter combination generally caused significant increases in yield over calcium arsenate alone, whereas the former did not. Less than 0.5 per cent of rotenone in calcium arsenate and less than 0.25 per cent in calcium arsenate-sulfur were not very effective in keeping the aphid population down. Calcium arsenate plus 0.5 per cent of rotenone gave larger, but not significant, increases in

yield and fewer aphids than calcium arsenate-sulfur plus 0.25 per cent of rotenone. The records obtained at Tallulah showed that derris, cube, and timbo were equally effective as sources of rotenone. The records at Florence showed that sulfur, diatomaceous earth, clay, pyrophyllite, and walnut-shell flour were equally effective as diluents for calcium arsenate and rotenone.

In general, the data from these experiments confirm the results of earlier investigations. In locations where boll weevil control was not a factor, the plots treated with the calcium arsenate-rotenone mixtures were comparable with the untreated check plots in both aphid population and yield. Where boll weevil control was a factor, these mixtures gave highly significant increases in yield over the check plots and significant increases over the calcium arsenate plots.—3-27-42.

LITERATURE CITED

Bondy, Floyd F., and C. F. Rainwater. 1939. Boll weevil and miscellaneous cotton insect investigations. S. C. Expt. Sta. Ann. Rept. **52**: 124–34.

Bondy, Floyd F., and C. F. Rainwater. 1941. Dusting for boll weevil and cotton aphid control. U. S. Dept. Agr., Bur. Ent. and Plant Quar. E-538.

Rainwater, C. F., and Floyd F. Bondy, 1941-a. Combinations of insecticides for control of boll weevil and cotton leaf aphid. JOUR. ECON. ENT. **34**(2): 297–300.

Rainwater, C. F., and Floyd F. Bondy. 1941-b. Boll weevil and cotton aphid control by the use of derris in combination with calcium arsenate. JOUR. ECON. ENT. **34**(6): 733–735.

Insecticidal Control of Legume Bugs in Seed Alfalfa[1]

R. A. FISHER and W. E. SHULL,[2] *University of Idaho, Moscow*

Legume bugs, particularly the legume bug, *Lygus hesperus* Kngt., and the pale legume bug, *Lygus elisus* Van D., have been found to be a contributing factor to many of the failures in the production of alfalfa seed in the western states. Stitt (1941) has outlined certain cultural practices which show promise of reducing the injury from these insects in areas devoted exclusively to the production of alfalfa seed. These practices were followed in one seed-producing section of Idaho in 1940 with promising results. In 1941 the cultural control program was unsuccessful because of the late, rainy spring, which interfered with the establishment of uniform cutting dates and which kept weed hosts green, producing large numbers of the insects which later moved to alfalfa. There are, also, many areas in which seed fields are intermingled with hay and other crops and in which these cultural practices could not be successfully applied. For such areas and in seasons when cultural practices cannot be successful, control of legume bugs by means of insecticides is desirable.

McGregor (1927) reported satisfactory control of *Lygus elisus* on cotton with resublimed dusting sulfur. Sorenson (1939), however, found dusting sulfur to have a repelling effect upon legume bugs rather than killing them. He found dusts containing pyrethrum most effective of several materials tested but concluded that none of the insecticides tested were sufficiently effective to justify costs of application. Carlson (1940) reported preventing damage on small plots by repeated applications of a pyrethrum-sulfur dust. Moore & Fox (1941) were able to control adults of several *Lygus* species, including *L. elisus*, on peaches with a dust containing 0.2 per cent pyrethrins. Smith and his co-workers (1937, 1941) have made cage tests with several insecticides against the tarnished plant bug, *Ligus oblineatus* (Say). They found pyrethrum and derris to be equally effective and better than other materials tested. Some mortality resulted from various mixtures of paris green, calcium arsenate, and sulfur.

EXPERIMENTAL.—A limited number of tests in 1937 indicated that pyrethrum preparations were effective against caged legume bugs but were ineffective in the field. Further tests in 1937 with caged legume bug adults showed that kills approaching 100 per cent could be obtained with pyrethrum dusts containing 0.2 to 0.3 per cent pyrethrins.

[1] Published with the approval of the Director of the Idaho Agricultural Experiment Station as Research Paper No. 206.

[2] Assistant Entomologist and Entomologist, respectively, of the Idaho Agricultural Experiment Station, Moscow, Idaho.

Laboratory studies were again resumed in 1940 and 1941 to determine the effectiveness of various dust preparations as insecticides for legume bug control. The equipment used was essentially that described by Fisher (1939). The legume bugs were collected by sweeping alfalfa with an insect net. The insects collected

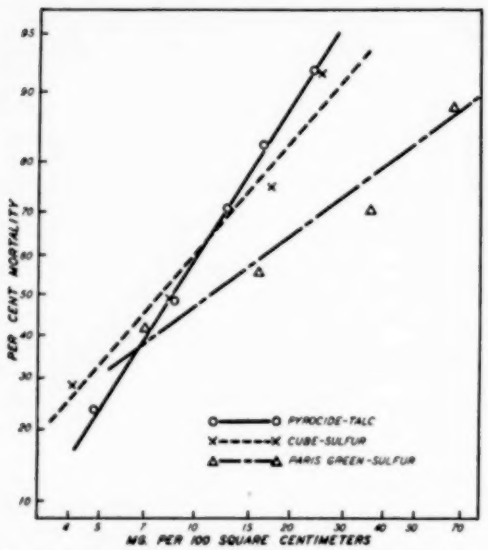

FIG. 1.—Dosage-mortality curves for legume bug adults with pyrethrum, cube, and paris green dusts.

were put in a screen cage and brought into the laboratory where they were separated from other sweepings by allowing them to fly or crawl to the screen of an open window. They were then taken from the window screen with an aspirator and transferred to small screen cages to be dusted. A fresh lot of insects was collected for each half day of testing.

Two cages, each containing 25 insects, were placed on the dusting stand with two pieces of weighed millimeter paper and covered with a bell jar. After dust blown into the jar had settled, the papers were reweighed to determine the amount of dust applied. The dusted insects were transferred to glass vials covered with cloth caps and kept at room temperature for observation of mortality. A piece of blotting paper was placed in the bottom of each vial to absorb moisture, and a sprig of fresh alfalfa was supplied for food each half day. A series of untreated check insects and usually a series of checks dusted with inert carriers were run with each experimental series.

Final readings of mortality were made 24 hours after dusting. Percentage mortalities were calculated from the numbers of paralyzed and dead individuals at the end of this time. Observations over longer periods showed that insects still paralyzed at the end of 24 hours never recovered from the effects of the dust. The mortalities of undusted checks were seldom over 4 per cent and were ignored in calculating the mortalities caused by the insecticides. All tests in which the amounts of dust were nearly the same were combined and an average dosage and per cent kill obtained from the group.

The predominant species available for laboratory work was *Lygus atriflavus* Kngt. *Lygus elisus* Van D. and *L. hesperus* Kngt. were also present in varying numbers. No attempt was made to segregate the insects by species in the work reported below because there was no appreciable species difference in their reactions to a dust containing rotenone and pyrethrum.

All pyrethrum dusts were prepared with *Dry Pyrocide*,[1] and all dusts containing rotenone were prepared with a sample of cube containing 3.5 per cent rotenone and 14.6 per cent total extractives.

RESULTS.—The relative effectiveness of 0.25 per cent pyrethrins in talc, 0.88 per cent rotenone in sulfur, and 25 per cent paris green in sulfur was first compared against legume bug adults. The paris green used contained not less than 50 per cent As_2O_3. Results of these tests are shown in figure 1.

Analysis of the data shows no significant difference between the pyrethrum and cube dusts, but the paris green sulfur dust is much less toxic than the other two.

A number of tests were made with cube dusts with sulfur, diatomaceous earth and talc as carriers. There was no difference in the results with any of these dusts. The addition of 3 parts by weight of steam-distilled pine oil to a cube-sulfur dust did not increase its effectiveness.

Preliminary laboratory and field experiments indicated that legume bug nymphs were more resistant to the insecticides being tested than were the adults. Experiments were therefore conducted to determine the difference between the resistance of legume bug nymphs and adults to pyrethrum and cube dusts. Nymphs of the 3d, 4th, and 5th instars and adults were

[1] A proprietary dust containing 2 per cent pyrethrins.

dusted simultaneously in separate cages under the bell jar. The pyrethrum dust contained 0.25 per cent pyrethrins in a talc carrier; the cube was mixed with sulfur and contained 0.88 per cent rotenone. Results of these tests are given in table 1.

Table 1.—Mortalities of legume bug adults and nymphs from equal dosages of pyrethrum and cube dusts.

Mg. per 100 sq. cm.	Per cent Kill	
	Nymphs	Adults
PYRETHRUM		
11.0	18.4	49.0
14.4	37.2	76.8
25.9	50.0	87.7
47.5	79.6	100.0
CUBE		
12.0	28.8	55.0
19.2	47.3	74.1
27.6	39.6	94.3
50.5	35.4	100.0

These data clearly show a difference between the resistance of the nymphs and adults to pyrethrum and cube dusts. The mortality of the adults is nearly twice that of the nymphs. The results with the cube dust are also of particular interest. Increasing the dosage of this dust did not increase the mortality of the nymphs. This material could not, therefore, be expected to give good control of legume bugs in the field when nymphs were present.

Tests were made next with a combination dust of pyrethrum and cube in a talc carrier, containing 0.25 per cent pyrethrins and 1.0 per cent rotenone. This dust was compared with nymphs and adults as described above. Results are given in table 2.

Table 2.—Mortalities of legume bug nymphs and adults from a combination pyrethrum and cube dust.

Mg. per 100 Sq. Cm.	Per Cent Mortality	
	Nmphs	Adults
5.3	34.7	62.0
7.8	35.2	73.6
10.3	43.0	89.3
14.9	71.2	100.0
24.0	87.6	100.0
31.8	96.9	100.0

This dust mixture also was more effective against the adults than the nymphs. However, it is of particular interest because of the high toxicity to both nymphs and adults. The combination pyrethrum-cube dust is as toxic to nymphs as pyrethrum alone is to adults (Fig. 2).

It was desirable to know the lower limits of pyrethrin and rotenone content of a combination dust that would give satisfactory results. Tests with legume bug nymphs were made with varying percentages of pyrethrins in dusts containing 1.0 per cent rotenone. During June no difference was found between dusts containing 0.25 and 0.10 per cent pyrethrins in 1.0 per cent rotenone. During July, however, it was found that the nymphs were more resistant to the dusts than in June, and this work was repeated. Results with three pyrethrum-cube dusts during July are shown in figure 3. Analysis of these data shows significant differences between all of the dusts. The difference between the dusts containing 0.25 and 0.125 per cent pyrethrins is so small, however, that it probably would not be appreciable in field control.

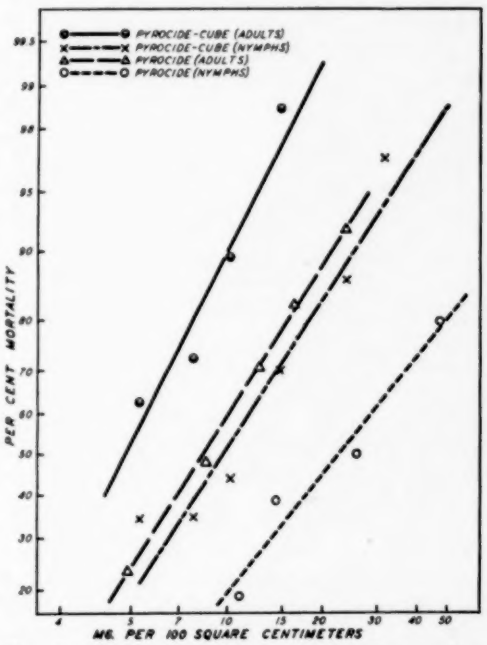

FIG. 2.—Dosage-mortality curves for legume bug nymphs and adults with pyrethrum and pyrethrum-cube dusts.

There is no completely satisfactory explanation for the change in the resistance of the nymphs between June and July, although it is quite possible that climatic

factors were important. During June there was considerable cool, rainy weather, while in July temperatures were higher with little rainfall. There is also the possibility that in collecting from damp plants in June the nymphs may have been injured and weakened to some extent.

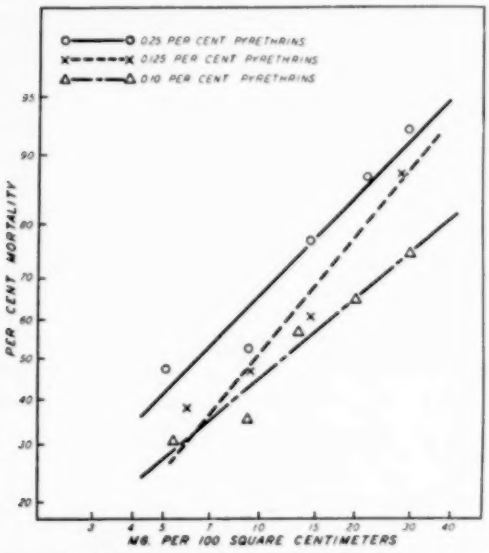
0.25 PER CENT PYRETHRINS
0.125 PER CENT PYRETHRINS
0.10 PER CENT PYRETHRINS
PER CENT MORTALITY
MG. PER 100 SQUARE CENTIMETERS

FIG. 3.—Dosage-mortality curves for legume bug nymphs with dusts containing 1.0 per cent rotenone and varying percentages of pyrethrins.

Further tests with three mixtures containing 0.125 per cent pyrethrins and 1.0, 0.50, and 0.25 percent rotenone, respectively, indicated that the rotenone content could be cut to 0.50 per cent without materially reducing the effectiveness of such a dust. The combination dust, therefore, should contain 0.125 per cent pyrethrins and 0.50 per cent rotenone.

Several alfalfa seed growers have reported that alfalfa dusted with sodium arsenite for mormon cricket control has given better blossom set and increased yields over undusted alfalfa, possibly because of some control of legume bugs. Laboratory tests to determine the toxicity of sodium arsenite to these insects were conducted. A few tests were made with nymphs. Although the data obtained were too limited to be conclusive, they did indicate that a 20 per cent sodium arsenite dust was as toxic, and possibly more so, than a dust containing 0.125 per cent pyrethrins and 0.50 per cent rotenone.

Investigations of these materials were continued with legume bug adults, with the results shown in figure 4. A 20 per cent sodium arsenite dust was prepared with diatomaceous earth as a carrier, and 10 per cent dusts were prepared with either diatomaceous earth or talc as carriers. There was no difference in the two carriers, and the data obtained were combined for computing the dosage-mortality curve.

There is no significant difference in position of the dosage-mortality curves for pyrethrum-cube and 20 per cent sodium arsenite dusts. There is a highly significant difference in slope, indicating that at the higher dosages the pyrethrum-cube is more toxic. The 10 per cent sodium arsenite dust is decidedly inferior to the other two dusts.

FIELD CONTROL OF LEGUME BUGS.—Field experiments with insecticides for legume bug control were made in 1938, 1940, and 1941. Fields treated with a py-

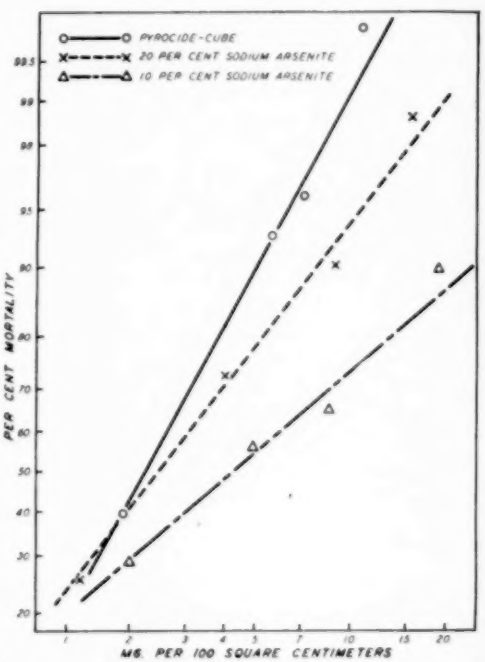

FIG. 4.—Dosage-mortality curves for legume bug adults with pyrethrum-cube and sodium arsenite dusts.

rethrum dust containing 0.25 per cent pyrethrins in 1938 showed a marked reduction of the insects after the dust application. Populations remained at a low point throughout the rest of the season. Check fields, however, also showed a tendency toward low populations during the latter part of the season.

Dusts containing pyrethrum, rotenone, and paris green were tested on small field plots in 1940. The best results were obtained with the pyrethrum dust, but this material gave only a 45 per cent reduction of the insects when applied just as the plants were beginning to bloom. A second application 2 weeks later gave no control with any of the materials.

A pyrethrum-cube mixture containing 0.25 per cent pyrethrins and 1.0 per cent rotenone was the only material used in 1941. This dust was applied to 5-acre plots, some of which were dusted once and some twice. Kills were poor when 25 pounds per acre were applied, but approached 90 per cent when 35 pounds per acre were applied shortly before the plants began to bloom. Results with the second application, when the plants were larger, were not as good as with the first. In all instances the plots were heavily reinfested within a few days, and no benefit was derived from the control operations.

Although power-driven dusters with canvas trailers over the nozzles were used both in 1940 and 1941, the results were not satisfactory when plant growth was heavy. This indicates a need for better dusting equipment which will distribute the dust more thoroughly through the plant growth, especially after the plants reach the blossom stage.

The performance of sodium arsenite has not been critically checked in field tests. This material will be tried in the field since its toxicity, as shown in the laboratory, indicates that it may be of value for legume bug control.

SUMMARY.—A dust mixture of *Dry Pyrocide* and cube, containing 0.125 per cent pyrethrins and 0.50 per cent rotenone, gave good kills of legume bug nymphs and adults in laboratory experiments. Kills approaching 90 per cent were obtained in the field with a pyrethrum-cube dust, but the fields were soon heavily reinfested, and no benefit was derived from the control operations.

A 20 per cent sodium arsenite dust gave good laboratory control of the insects and may be of value in field control.—2-10-42.

LITERATURE CITED

Carlson, John W. 1940. *Lygus* bug damage to alfalfa in relation to seed production. Jour. Agr. Res. **61**(11): 791–815.

Fisher, R. A. 1939. A dust delivery tube for laboratory experiments with contact insecticides. U.S.D.A. Bur. Ent. and Plant Quar. ET-151.

McGregor, E. A. 1927. *Lygus elisus:* a pest of the cotton regions in Arizona and California. U.S.D.A. Tech. Bul. 4.

Moore, J. B., and C. C. Fox. 1941. *Lygus* injury to peaches in the pacific northwest and its prevention. JOUR. ECON. ENT. **34**(1): 99–101.

Smith, G. L., and A. L. Scales. 1937. Toxicity of a number of insecticides to three cotton insects. JOUR. ECON. ENT. **30**(6): 864–9.

Smith, G. L., A. L. Scales and R. C. Gaines. 1941. Further studies of various insecticides against three cotton insects. JOUR. ECON. ENT. **34**(2): 310–13.

Sorenson, C. J. 1939. *Lygus* bugs in relation to alfalfa seed production. Utah Agr. Expt. Sta. Bul. **284.**

Stitt, Lloyd L. 1941. An experimental cooperative community program for the cultural control of bugs of the genus *Lygus* on alfalfa seed crops in the Mohawk area of Arizona in 1939 and 1940. U.S.D.A., Bur. Ent. and Plant Quar. E-546.

MEXICAN FRUITFLY FOUND IN ILLINOIS

In late April, 1942, one of our clients submitted a single grapefruit which was infested with a half-dozen maggots of the Mexican fruitfly, *Anastrepha ludens*. The fruit in which the maggots were found bore the stamp of one of the fruit companies in Texas, so that it appears probable that this species is established in that section of the United States. Several dozen grapefruits which were supposed to have been a part of the same shipment from which the infested fruits came, were secured and examined, but not a single maggot was found in any of them. Part of them bore the same trademark stamp as the infested fruit.—7-6-42.

C. L. METCALF
University of Illinois, Urbana

Manual Infestation of Corn Strains as a Method of Determining Differential Earworm Damage[1]

RALPH A. BLANCHARD and A. F. SATTERTHWAIT, *Bureau of Entomology and Plant Quarantine*, and RALPH O. SNELLING, *Bureau of Plant Industry, U. S. Department of Agriculture*

Natural infestation by the corn earworm, *Heliothis armigera* (Hbn.), particularly in the Corn Belt, is not always of sufficient intensity to provide an adequate test of the relative resistance of different corn strains. Also, corn strains differ in time of silking, and in an experiment containing a large number of strains all may not be in a uniform condition for infestation. Consequently a method of controlled infestation is highly desirable.[2]

MATERIALS AND METHODS.—The data given herein were obtained from studies made during the years 1936 to 1941, inclusive. The experiments in 1936 were designed to determine the best method of controlled infestation with the earworm. In similar work with the European corn borer good results had been obtained by attaching egg masses to the corn leaves, thereby simulating natural conditions (Patch & Peirce 1933). The attaching of earworm eggs to the corn silks did not appear feasible because the earworm moth lays its eggs singly, but several such attempts were made. Furthermore, the presence of predators among the silks, especially the hemipteron *Orius insidiosus* (Say), increased the uncertainty of obtaining adequate infestation with the eggs. It was therefore decided to place newly hatched larvae on the silks.

Since all forms of the earworm are scarce in central Illinois early in the season, the initial larvae in 1936 were collected from corn and tomato fields in southern Illinois and southeastern Missouri. These were supplemented with larvae taken from refrigerator cars carrying shipments of early-market corn from the South. Some larvae were also collected from this early corn in the local markets.

After 1936 larvae were collected in the fall and the resulting pupae kept in storage at a temperature of about 45° F. until time to set up rearing cages the following season. Later in the summer large larvae were collected from local cornfields and reared to adults. Surplus pupae were placed in cold storage at about 45° until needed.

The sex of each pupa was determined and the sexes separated prior to emergence. The pupae were placed on moist sand under lantern-globe cages a few days before the adults were expected to emerge. Upon emergence, males and females of approximately the same age were placed together in oviposition cages.

Several types of cages were tried and, from the standpoint of the number of fertile eggs obtained, as well as convenience, a screen cage 12 by 12 by 12 inches in size appeared to be the most practical. A cage somewhat similar to that described by Briand (1929), having circular wooden ends held together by four long stove bolts, around which waxed paper was tighly fastened to form a cylindrical enclosure, was also satisfactory. Cages made of fruit jars or lantern globes did not appear to be so satisfactory, largely because they were not so easy to manipulate.

Unless special precautions were taken, the females would oviposit at random on all parts of the interior of the cage. To avoid this in the screen cage, a section of good-quality cheesecloth was placed over the inside of the door, and this portion of the cage was faced toward the light. The tops of these cages were darkened by placing one cage upon the other or by covering the tops with wrapping paper. In both the screen cage and the waxed-paper cage a strip of cheesecloth 1.5 to 2 inches wide was suspended hammock-like across the cage. It was estimated that in the screen cages 90 per cent of the eggs were laid on the cheesecloth and could easily be removed. Most of the eggs were deposited near the upper margin of the cheesecloth covering the screen or near the points of attachment of the cheesecloth strips. In the waxed-paper cage a portion of the eggs were usually deposited on the paper, which could be rolled off when the eggs were to be removed.

[1] Cooperative investigations of the U. S. Department of Agriculture, the Illinois Natural History Survey, and the Illinois Agricultural Experiment Station.

[2] Acknowledgment is due J. M. Magner, formerly of the Bureau of Entomology and Plant Quarantine, for aid in carrying out certain phases of the work.

Several kinds and concentrations of liquid foods for the moths were compared. Most of them were unsatisfactory and only two provided a diet that permitted the female to lay eggs in any considerable number. One satisfactory food consisted of a solution containing approximately 15 cc. of strained honey and 85 cc. of distilled water, to which a piece of fresh yeast about the size of a pea had been added. It was necessary for this solution to ferment a day or two before it became a suitable food. After 3 or 4 days at summer temperatures, however, the solution tended to become unsuitable for food, probably because of excessive fermentation, bacterial contamination, or in some cases the formation of vinegar. Beer proved to be the most satisfactory food.[1] Canned beer that had not been cooled was more satisfactory than beer that had been refrigerated and then allowed to become warm. During 1939 an estimated average of 275 eggs per female were obtained from 176 females fed beer exclusively, whereas an estimated average of 140 eggs per female were obtained from those receiving only fermented honey-water solution. Even with beer as food the average number of eggs per female was not large. Factors other than food undoubtedly influenced the rate of oviposition. It was observed that females in the 12-by-12-by-12-inch cages containing several pairs of adults were more likely to have a high oviposition rate per female than those in cages containing only one or two pairs of adults.

The cheesecloth and waxed paper to which eggs were attached were removed from the cages and cut in length containing up to 200 eggs. These strips were rolled loosely and placed in 35-mm. by 100-mm. glass vials with a portion of the eggs facing outward, in order that the stage of development might easily be ascertained. Plugs of moist sterile absorbent cotton, over which cheesecloth was stretched, were inserted in the open ends of the vials. The cheesecloth covering prevented the young larvae from becoming entangled in the cotton upon hatching. The vials containing the eggs were placed in an outdoor screenhouse. If shortening of the incubation period was desired, the eggs were placed in a small incubator and the temperature was kept at 90 to 95° F. Eggs so treated hatched in less than 2 days, whereas those in the screened section of the insectary usually required from 2 to 4 days, depending on the temperature. If a surplus of eggs accumulated, they were placed in a refrigerator at approximately 45°.

It was found that eggs could be stored in this manner for 5 or 6 days without danger of being killed. Development took place very slowly at that temperature, and upon removal from the refrigerator an additional day or two was required for the larvae to develop and hatch, depending on the temperature and length of time the eggs were in the refrigerator.

The larvae were placed on the corn silks as soon as possible after hatching. In order to prevent cannibalism during the period required for placing the larvae, all the vials except those from which larvae were being removed were placed in a small portable refrigerator. Usually two or three vials were taken into the plots at one time, and while larvae were being removed from one the others were kept in the operator's shirt pocket. Since the larvae always crawled upward, the vials were inverted every few minutes to keep the larvae from becoming crowded at one end.

In the placing of larvae on the corn silks, the open end of the vial was held upward and as the insects crawled toward the rim they were carefully removed, one at a time, by means of a small camels-hair brush, which was frequently moistened in the operator's mouth. The side of the brush near the tip was used in removing the larvae in order to prevent possible injury to them by the bristles. Only active larvae were used in making the infestations. The larvae were distributed at different points on the silk mass in an attempt to keep them from meeting in the silk channel on their way under the husk. Observations showed that most of the larvae started into the ear tip very soon after being placed on the silks. Most of them passed from view under the husks in less than 3 minutes.

From two to seven larvae were placed on each ear. When more than four larvae were placed on the ears the infestations were made on 2 days. In 1940 seven larvae were placed on most of the ears infested.

[1] The use of beer as food for the corn earworm adult was suggested to the writers by D. W. La Hue, Bureau of Entomology and Plant Quarantine.

Four were placed on the silks 2 to 4 days after the first silk appeared and three more after an interval of 3 to 6 days. From a special study made in 1941 it would appear that as good results could be obtained by placing a total of five larvae on the silks in the same manner.

The manual-infestation method was used in tests with both naturally pollinated ears and ears on which pollination was controlled. The dates of silking and infestation of the naturally pollinated ears were recorded on tags wired to the plants. Such data were recorded on one corner of the pollination bag in the tests with controlled pollinated ears.

Hand-pollinated ears were infested from 2 to 3 days after the pollen was applied. The pollination bag was loosened temporarily and the larvae were placed directly on the silks. Two men usually worked together in making the infestations in order to reduce the possibility of introduction of stray pollen from the surrounding plants. One man loosened the bag and lifted it above the silk high enough to allow the other worker to place the larvae but low enough to shield the silks from foreign pollen. The bag was replaced immediately after the ears were infested.

DISCUSSION.—Four years' results have shown that larvae became established on an average of over 90 per cent of the artificially infested ears regardless of the number of larvae placed on the silks. In a special study involving 218 ears, in which two larvae were placed on the silks of each ear shoot, both larvae reached the last instar on 27 and one larva developed on 191 of them.

Some strains of corn appear to permit a higher rate of larval survival than others, although data on that point are rather limited.

Damage resulting from larvae placed on the silks by hand was not always so great as damage to the same strains under relatively severe natural infestations. The severity of the infestation may depend to a great extent on the number of times the ears are infested. Ears receiving two applications of larvae were 95.7 per cent infested whereas those receiving one application were 87.8 per cent infested. The extent of damage to the infested ears was judged on the basis of five damage classes. Class 1 represented very slight damage and class 5 very severe damage. The average class of damage, where the five classes were used, was 2.7 for ears receiving two infestations and 1.9 for ears with one infestation, the lower classes indicating less damage. The average percentages of damaged ears which were worse than class 2 were 59.8 for those infested twice and 24.7 for ears infested once.

Manual infestations were made on ears that had been covered by bags for hand pollination as well as on ears left open to natural pollination. Damage by artificial infestation was slightly greater on hand-pollinated ears than on naturally pollinated ears. The average class of damage under the bags was 2.4 as compared with a damage of 2.0 in the absence of bags. Thus it appears that artificial infestation can be effectively used, either in connection with breeding operations where pollination is controlled or in connection with the testing of strains under open pollination. Artificial infestation has the additional advantage in that it can be made fairly unform from year to year, whereas natural infestations are subject to interannual variations.

The use of manual infestation has shown that some corn varieties contain segregates that show promise of being highly resistant. Therefore the method appears to offer a means of simultaneous selection and breeding for resistance to the cornear worm.

SUMMARY.—Moths for oviposition cages were obtained from large larvae collected from early market corn shipped from the South, from early sweet corn, or from pupae collected from late corn the previous year and kept in a cool place throughout the winter.

Screen-wire cages 12-by-12-by-12-inches in size containing several pairs of moths were successfully used.

Beer that had not been cooled was the most satisfactory food, although a solution of strained honey, distilled water, and yeast was fairly satisfactory.

The eggs were laid on small strips of cheesecloth suspended inside the cages. Sections of these strips containing up to 200 eggs were placed in 35-by-100-mm. vials plugged with moist cotton.

The larvae were placed on fresh corn silks as soon as possible after hatching, although surplus eggs were safely held in storage at 45° F. for as long as 6 days. A

moistened camels-hair brush was used in placing larvae on the silks.

From five to seven larvae per ear, two to four placed at one time and the remainder after 3 to 6 days, resulted in the most severe damage to the test ears.

Manual infestation can be used effectively in corn-breeding operations by placing the larvae on silks under the pollination bags.

This method of infestation can be uniform from year to year, whereas natural infestations are subject to wide interannual variations.—2-14-42.

LITERATURE CITED

Briand, L. J. 1929. Laboratory breeding of the European corn borer (*Pyrausta nubilalis* Hubn.) with special reference to equipment and cages. Canad. Ent. **61**(3): 51–4.

Patch, L. H., and L. L. Peirce. 1933. Laboratory production of clusters of European corn borer eggs for use in hand infestation of corn. JOUR. ECON. ENT. **26**(1): 196–204.

Control of Earworms in Corn by Birds[1]

GEO. W. BARBER, *U. S. Department of Agriculture, Bureau of Entomology and Plant Quarantine*

Larvae of the corn earworm, *Heliothis armigera* (Hbn.), feeding within corn ears are usually protected from natural enemies to a high degree by the husks. Often thousands of larvae are handled without parasitization being observed. Predacious insects rarely enter the ears to search for larvae, and most enemies other than insects cannot obtain access to the larvae to devour them. The only natural enemies seemingly fitted to reach the larvae in corn ears are certain species of birds that possess beaks suitable for puncturing the husks. Ordinarily the extent of bird feeding is not greater than 1 per cent of the ears in a given field. Therefore, when relatively high control by birds is found, as in the present instance, the subject is of sufficient interest to justify careful examination.

The field in which earworms were controlled by birds consisted of about 5 acres of white dent field corn, which was in roasting-ear stage of development between July 20 and 30, 1931. It was on Wormsloe Plantation in Chatham County, Ga. The crop was grown for ensilage and was harvested during the last few days in July. The plantation, located on the Coastal Plain, consisted of a few scattered, cultivated fields surrounded by woodlands and roadside trees, but on the whole there was much more woodland than cultivated area. The cornfield in question was bounded on the west by a road bordered on each side by a double row of live oaks, and beyond the road lay a large cultivated field. On the north were farm buildings shaded by large live oaks, and beyond these lay cultivated fields interspaced with woodland. To the east was a pasture, shaded by oaks, gums, and other trees, and to the south was a thick mixed forest. To the southwest, beginning about 100 yards from the cornfield, was a virgin pine forest of hundreds of acres.

Although a large and mixed population of birds occurred in the area described, puncturing of the ears to extract larvae probably was the work of hairy woodpeckers, which were observed daily engaged in this activity. Other birds, namely, various species of warblers, mockingbirds, orioles, blackbirds, and loggerhead shrikes, searched over the corn plants and may have been able to take larvae from the tips of the ears, especially from those having short or loose husks, through which larvae could be reached easily. They probably also took migrating *Laphygma* larvae.

Between July 24 and 29 a thousand ears from this cornfield were examined. The ears were taken from consecutive plants in rows in different parts of the field, throughout which bird feeding was relatively evenly distributed. It was found that 96.1 per cent of the ears were, or had been, infested by caterpillars, and that 3.9 per cent were uninfested. A total of 203 larvae were found in the ears. Of these, 65 per cent were *Heliothis armigera*, consisting of 47 sixth instars, 44 fifth instars,

[1] The species of earworms involved are the corn earworm, *Heliothis armigera* (Hon.), and the fall armyworm, *Laphygma frugiperda* (A. and S.).

31 fourth instars, and 10 third instars. The remaining 35 per cent were fall armyworms, *Laphygma frugiperda*, and consisted of 11 sixth instars, 27 fifth instars, 18 fourth instars, 14 third instars, and 1 first instar.

The condition of the thousand ears with respect to infestation by larvae and attack by birds in relation to injury of the kernels is shown in table 1. Of the 100 ears that bore larval exit holes only 6 were punctured by birds, and these may have been ears in which more than 1 larva had been feeding, the larger of which had become full grown and had gnawed its way out of the ear. Of the 39 ears that were not infested by caterpillars none were attacked by birds. Therefore it seemed probable that the birds were able to determine whether an ear contained a caterpillar. Apparently also they were able to locate the exact spot within the ear where the caterpillar was lying.

Of the 867 infested ears without larval exit holes, 155 contained larvae but showed no bird punctures, 35 contained larvae and also showed bird punctures (ears that probably contained more than 1 larva, the larger of which had been taken by birds), and 677 contained no larvae but showed bird punctures.

Of the 712 ears that had been attacked by birds 707 contained a single bird puncture and 5 contained 2 punctures. In 178 of these ears birds had gained access through the tip of the husk, and in 534 they had punctured the husk below the tip, the total number of such punctures being 539.

Usually birds took the larvae before the latter had penetrated far enough into the ears to injure the kernels, but this was dependent, in part, on the length of the husk beyond the cob. Information on the relation of the length of the husk beyond the cob to the location from which larvae were taken by birds is given in table 2. These data show that, as the husk extended farther beyond the cob, the percentage of bird punctures occurring beyond the cob-tip was proportionately greater and the number of ears that received kernel injury by larvae was less.

Of the 100 ears having larval exit holes, and in which larvae had attained full growth, the husks were variously developed. The location of the exit holes ranged from 3 inches above to 4.6 inches below the tip of the cob. Fifty-two larvae gnawed exit holes above the tip, 3 exactly at the tip, and 45 below the tip. Kernel injury was invariably found when exit holes occurred below the tip.

On the basis that 87 of the 100 ears in which larvae had become full grown and had gnawed exit holes received kernel injury, 619 of the 712 ears that birds attacked would have been liable to kernel injury if the larvae had completed development and had not been removed by birds. Of the ears attacked by birds 134 sustained kernel injury. Therefore, it seems likely that 485 ears had been protected from kernel injury. Since 712 of the

Table 1.—Relation of *Heliothis* and *Laphygma* infestation and bird attacks thereon to kernel injury in corn ears.

Condition of Ears	Number of Ears	Uninjured Ears, Per Cent	Percentage of Ears Injured in the Following Parts		
			Small Kernels at Tip Inch of the Cob	Kernels of Intermediate Size Just Below Tip	Large Kernels of Uniform Size
Not attacked by birds					
Uninfested	39	100.0	—	—	—
Infested:					
With larval exit holes, larvae having fed to maturity	100	13.0	87.0	41.0	3.0
Without larval exit holes; immature larvae present	155	54.8	45.2	14.8	0.6
Attacked by birds. Larvae had fed but were not present	712[1]	81.0	18.8	1.7	0.1

[1] Six ears showed both larval exit holes and bird punctures. Ears in which kernels of intermediate size were injured also showed injury to small tip kernels. Ears in which large kernels were injured also showed injury to the small and intermediate sized kernels.

Table 2.—Relation between the extension of the husk beyond the cob and the part of the corn ear from which birds took larvae of *Heliothis* and *Laphygma*.

Extension in Inches Above Tip of Cob	Number of Ears	Ears Having Husk Extension of Stated Length, Per Cent	Distribution of Bird Punctures					
			Above Tip of Cob[1]		At Tip of Cob[2]		Below Tip of Cob[3]	
			Number of Ears	Per Cent of Total	Number of Ears	Per Cent of Total	Number of Ears	Per Cent of Total
None	6	0.8	—	—	5	83.3	1	16.7
0.1 to 1.0	34	4.7	24	70.6	—	—	10	29.4
1.1 to 2.0	133	18.6	108	81.2	3	2.3	22	16.5
2.1 to 3.0	186	25.9	164	88.2	3	1.6	19	10.2
3.1 to 4.0	188	26.2	173	92.0	2	1.1	13	6.9
4.1 to 5.0	102	14.2	96	94.1	2	2.0	4	3.9
5.1 to 6.0	49	6.8	48	98.0	—	—	1	2.0
6.1 to 7.0	17	2.4	17	100.0	—	—	—	—
7.1 to 8.0	2	.3	2	100.0	—	—	—	—
Total	717[4]		632	88.2	15	2.1	70	10.0

[1] Larvae did not reach the kernels before birds took them.
[2] Larvae reached the tip of the cob before birds took them, but they may not have injured the kernels.
[3] Larvae reached and injured the kernels before birds took them.
[4] Of 712 ears attacked by birds, 5 showed 2 punctures each.

1000 ears that were examined had been attacked by birds, and 48.5 per cent of them were protected against kernal injury because birds had removed the larvae, it follows that 34.5 per cent of the ears in the cornfield had been protected against kernel injury.

If birds removed one larva from each of the 712 ears they attacked, the total extent of their feeding in this field, estimated on a crop of 9000 ears per acre, was 32,040 larvae. In addition, the birds that could not puncture the husks undoubtedly took many larvae that exposed themselves temporarily in moving from one part of the plant to another, especially *Laphygma* during migration from the tassel to the ear.

The reason this field was protected to an unusual degree from injury to the kernels by earworms seems to have been the plentiful nesting sites available for a large bird population. The pine forest and the large oaks lining the roadways and scattered through pastures and about farm buildings contained many nesting sites for woodpeckers in particular, as well as for all the other birds observed, and seemed to have served as a reservoir from which the birds issued to feed upon any available food supply, in this case the insects inhabiting the cornfield. Most cornfields are not similarly protected because nesting sites, especially those suitable for woodpeckers, usually are not plentiful.

SUMMARY.—Description is given of a field of corn of about 5 acres in which birds had fed to an unusual extent upon larvae of *Heliothis armigera* (Hbn.) and *Laphygma frugiperda* (S. & A.) inhabiting the ears.

Infestation of ears by these insects was at the rate of 96.1 per cent. Of the larvae found in the ears 65 per cent were *Heliothis* and 35 per cent were *Laphygma*.

Birds, mainly the hair woodpecker, had attacked 712 of a thousand ears examined, usually having drilled through the husks to reach the larvae.

From a comparison of ears not attacked by birds and containing larvae or larval exit holes and the occurrence of kernel injury in such ears and in the ears that birds had attacked, it was found that in 345 of 1000 ears kernel injury had probably been prevented by birds which attacked and removed the larvae before the latter had penetrated far enough into the ears to reach the kernels.

The reason why a large proportion of the earworms in this field were attacked by birds seemed to be that favorable nesting sites for woodpeckers were plentiful in the adjoining or nearby woodlands and scattered shade trees. Usually cornfields are not surrounded by woodlands to a similar degree and fewer birds occur near the fields.—4-27-42.

Further Tests of Dichloroethyl Ether and of Jarring to Control Plum Curculio

OLIVER I. SNAPP, *U. S. Department of Agriculture, Bureau of Entomology and Plant Quarantine*

Experiments conducted by the writer in 1937 and 1938 indicated that soil treatment with dichloroethyl ether was worthy of further investigation as a possible substitute for spraying with lead arsenate in the control of the plum curculio, *Conotrachelus nenuphar* (Hbst.), on peach (Snapp 1939). The latter control method leaves much to be desired, especially because of the tendency of lead arsenate to injure the foliage, fruit, buds, and new wood of peach trees. The purpose of this paper is to report the results of further tests of this material in the laboratory in 1939 and 1940, under caged peach trees in 1939, 1940, and 1941, and in a commercial peach orchard in 1941. In some of the tests chemical treatments were combined with jarring to capture the adults.

EXPERIMENTS IN THE LABORATORY.—In 1937 and 1938, 1 gallon of liquid was used for each square yard of area to be treated. In 1939 and in later years tests were made to determine whether this quantity could be reduced. When the concentration of the diluted material was greater than 1 per cent, the ether was emulsified with a good grade of potash fish-oil soap by stirring 9 parts by volume of ether into 1 part of soap to give a 90-per cent stock emulsion.

In the laboratory experiments of 1939 dichloroethyl ether, one-third fluid ounce in one-third gallon of water was just as effective against plum curculio larvae as the same quantity in 1 gallon of water per square yard of soil. Not a single individual out of more than 750 larvae reached the adult stage in any of these experiments. When the liquid was reduced to one-sixth gallon of water and one-third fluid ounce of dichloroethyl ether per square yard of soil, the material was almost as effective against the larvae as the other two strengths, as only 17 out of 754 larvae reached the adult stage. One fluid ounce of dichloroethyl ether in either 1 gallon or one-third gallon of water per square yard of soil or 1 fluid ounce of that material in 7 fluid ounces of water (8 fluid ounces of 12.5 per cent emulsion of dichloroethyl ether) per square yare of soil gave a complete kill. Each of these sprays was used against more than 750 pupae in large pupation boxes.

Laboratory experiments in 1940 also indicated that a large water load is not necessary as a conveyer of the dichloroethyl ether to the soil cells, where plum curculio pupation takes place, when the spray is used against pupae. One fluid ounce of dichloroethyl ether in water (one-sixth gallon of 4.5 per cent emulsion) per square yard of very damp soil and 1 fluid ounce of dichloroethyl ether in 7 fluid ounces of water (8 ounches of 12.5 per cent emulsion) per square yard of very damp soil permitted emergence of only 9 and 8 adults, respectively, from the 750 pupae in each of the boxes receiving these sprays. Not a single individual reached the adult stage in the box in which 1 fluid ounce of the material in 1 gallon of water per square yard of very damp soil was used against 750 pupae. The more concentrated spray was not so effective against plum curculio larvae in thoroughly wet soil, as 104 out of 750 larvae reached the adult stage in the box sprayed with one-third fluid ounce of dichloroethyl ether in one-sixth gallon of water, whereas only 20 out of 750 larvae reached the adult stage in the box sprayed with one-third fluid ounce in 1 gallon of water. Sulfated alcohol did not improve the effectiveness of dichloroethyl ether against either plum curculio larvae or pupae.

Individual records taken in connection with these laboratory experiments showed that dichloroethyl ether at the rate of one-third fluid ounce per square yard of dry soil killed most of the plum curculio larvae within 3 days after treatment, whereas with similar treatment in thoroughly wet soil there were still some life larvae 15 days after application. Dichloroethyl ether at the rate of 1 fluid ounce per square yard of dry soil killed all plum curculio pupae within 2 days, whereas in very damp soil as long as 6 days were required when the material was used at the same rate.

EXPERIMENTS IN CAGED PEACH TREES.—During the season of 1939 each of 3 peach trees was artificially infested with approximately 465 curculio larvae in ad-

dition to those that were already present on the trees. The soil under each tree was given 2 applications of dichloroethyl ether, one at the rate of one-third fluid ounce in one-third gallon of water per square yard of soil when most of the insects were present as larvae and another at the rate of 1 fluid ounce in 1 gallon of water when most of the insects were pupae. Only one adult emerged from the caged trees.

During the season of 1940 each of 4 trees was artificially infested with approximately 350 plum curculio larvae in addition to those present on the trees. The soil under each tree received one application of dichloroethyl ether at the rate of 1 fluid ounce in one-sixth gallon of water (one-sixth gallon of 4.5-per cent emulsion) plus 0.2 per cent sulfated alcohol per square yard of soil. Only four adults emerged from the caged trees (Fig. 1).

During the season of 1941 each of four trees was artificially infested with approximately 883 plum curculio larvae in addition to those present on the trees. The soil under each tree was sprayed with one-sixth gallon of 1.5 per cent dichloroethyl ether emulsion per square yard of soil, chiefly against the larvae, and with one-sixth gallon of 4.5-per cent emulsion, chiefly against the pupae. Only 13 curculio adults emerged from the trees.

EXPERIMENTS IN A COMMERCIAL PEACH ORCHARD.—Experiments with dichloroethyl ether were carried on in a commercial peach orchard in 1941. Each of the five treatments was used on five replicates of 36 trees each, arranged in a latin square containing 900 trees.

The dichloroethyl ether was applied in the form of an emulsion at the rate of one-sixth gallon per square yard. When one-third fluid ounce per square yard was desired, a 1.5 per cent emulsion was used, and when 1 fluid ounce per square yard was called for, a 4.5-per cent emulsion was used. When two applications were made, the first was put on when practically all the insects were present as larvae and the second when most of the insects had become pupae; when only one application was made, it was put on when most of the insects were in the pupal stage. The experimental orchard received a sulfur fungicide 2 weeks after the shuck-off spray, 4 weeks before harvest.

The results were taken from four record trees in the middle of each replicate, and there were four barrier trees between the record trees of adjacent replicates, to prevent contamination by spray drift. At harvest time each of 4306 peaches in the samples from the 100 record trees was cut into halves, quarters, or eighths to determine definitely the percentage of the fruit infested with the curculio. Information on the treatments applied, and the results obtained, is given in table 1.

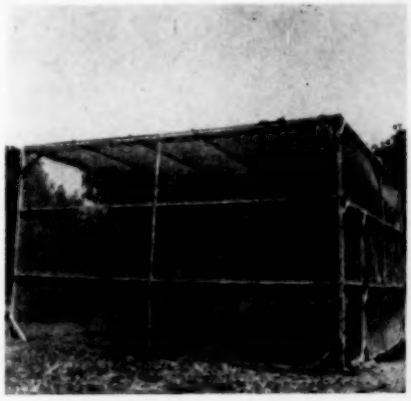

FIG. 1.—Type of cage over peach tree used in experiments in 1940 and 1941.

Table 1.—Summary of experiments for the control of the plum curculio, Fort Valley, Ga., 1931.

EXPERIMENT NO.	TREATMENT	PEACHES CUT AND EXAMINED	PER CENT INFESTED
1	Regular spray schedule (lead arsenate 2 lb. with hydrated lime 8 lb. per 100 gal. at petal-fall, shuck-off, and 4 weeks before haarvest)	736	8.0
2	Regular spray schedule; 1♀ jarrings for overwintered curculio adults and 7 jarrings for first-generation adults	956	4.1
3	Lead arsenate as in experiment 1 at shuck-off only; 1 application of dichloroethyl ether at 1 fluid ounce per square yard	713	11.7
4	One application of dichloroethyl ether at 1 fluid ounce per square yard; 1♀ jarrings for overwintered adults	869	11.5
5	Two applications of dichloroethyl ether at ½ and 1 fluid ounce per square yard; 1♀ jarrings for overwintered adults	1,032	7.2

The data were subjected to analysis of variance, but details are not given here. The results show that a program consisting of an application of one-third ounce of dichloroethyl ether per square yard

followed by another of 1 ounce per square yard, together with jarring to catch overwintered adults, is just as effective against the insect as the regular schedule of lead arsenate sprays on the fruit. Two applications of dichloroethyl ether, one chiefly against larvae and the other chiefly against pupae, gave much better curculio control

FIG. 2.—Condition of peach tree on September 12 after having received the regular schedule of lead arsenate during the season for plum curculio control.

than one application of this material directed against both stages of the insect. One application of lead arsenate at shuck-off and one application of dichloroethyl ether gave the same control as jarring to catch over wintered adults and one application of dichloroethyl ether.

The value of jarring as a supplementary measure in the control of the plum curculio attacking peaches is determined by the results of these experiments. Eight per cent of the fruit was wormy in the plots receiving the full schedule of lead arsenate sprays as compared with 4.1 per cent in the plots receiving these sprays plus jarring throughout the season to catch overwintered and new plum curculio adults.

No injury to vegetation under the spread of peach trees or to any part of the trees or foliage could be discerned from the two applications of dichloroethyl ether applied to the soil. With almost daily rains, the regular schedule of lead arsenate caused very heavy foliage injury and some injury to the fruit. The trees that had received the regular schedule of lead arsenate were from 90 to 95 per cent defoliated on September 12 (Fig. 2). As a result, many fruits buds opened in September, which may reduce the next season's fruit crop on these trees. The trees that received no lead arsenate during the season were in full foliage September 12 (Fig. 3).

SUMMARY.—The results of experiments conducted in the laboratory and on caged peach trees show that dichloroethyl ether is very effective against the plum curculio in the soil. In experiments conducted in a commercial peach orchard, two applications of dichloroethyl ether on the soil under the spread of the trees, plus 12 jarrings, gave as good control of the plum curculio as the regular schedule of lead arsenate sprays on the fruit. No injury to vegetation under the spread of the peach trees or to any part of the trees or foliage could be discerned from the two applications of dichloroethyl ether on the soil,

FIG. 3.—Condition of peach tree on September 12 after two applications of dichloroethyl ether for curculio control. No insecticide was used on foliage.

whereas the trees that had received the regular schedule of lead arsenate were from 90 to 95 per cent defoliated on September 12, following an especially favorable season for arsenical injury.—2-13-42.

LITERATURE CITED

Snapp, Oliver I. 1939. Dichloroethyl ether for the control of the plum curculio attacking peaches JOUR. ECON. ENT. **32**(4): 486–90.

Compatibility of Copper Fungicides with Nicotine Bentonite Insecticides

JACK E. FAHEY, *U. S. Department of Agriculture, Bureau of Entomology and Plant Quarantine*

Apple growers of southern Indiana and areas having similar climate must consider both insect and disease control in planning spray programs. Nicotine bentonite owes its usefulness as an insecticide to the formation of a water-insoluble compound which leaves a long-lasting residue on fruit and foliage. When bordeaux mixture is used with this insecticide, the nicotine bentonite is decomposed and the nicotine becomes water-soluble. Consequently both the quantity and the persistence of the nicotine residue are materially reduced.

Bordeaux mixture is the summer fungicide most widely used for control of apple diseases as well as those of other plants. Its use on truck crops sometimes results in injury to the foliage. In an effort to avoid such injury to truck crops the fungicide manufacturers have developed a number of other copper fungicides. Many of these materials are neutral in reaction and have been suggested for use on apples in combination with nicotine bentonite sprays.

Kadow *et al.* (1938) employed nine copper fungicides with a factory-processed nicotine bentonite spray mixture both in laboratory and field tests. They found that the nicotine bentonite insecticide increased the solubility of the copper fungicide from 1 to 50 times. Steiner & Fahey (1939), in field spraying experiments with five copper fungicides, combined with a tank-mix nicotine bentonite, found that the copper fungicides reduced the larvicidal efficiency of the nicotine bentonite residue and in addition were injurious to apple trees. The results reported by these two groups of workers indicate that copper fungicides and nicotine bentonite insecticides are not compatible.

From a chemical standpoint it was difficult to understand why bentonite or nicotine bentonite should increase the solubility of a copper compound in a fungicidal spray mixture. On the contrary we would anticipate the formation of a copper bentonite complex by base-exchange reaction between the copper salt and the calcium or nicotine bentonite.

To throw some light on this question a study was made of the water phase of spray mixtures of 17 copper fungicides with bentonite and with nicotine bentonite insecticides.

MATERIALS.—The nicotine bentonite insecticides and the copper fungicides, except basic cupric carbonate, were commercial spray materials. The fungicides were analyzed to determine the total-copper and soluble-copper content of the dry materials. The soluble-copper analysis was obtained by suspending 1 gram of the fungicide in 1 liter of recently boiled distilled water at room temperature (18°–21° C.), shaking intermittently for 8 hours, filtering, and determining the copper content of the filtrate by the carbamate colorimetric method. Table 1 gives the results of these analyses. The total-copper content of the fungicides ranged from 6.5 to 56.0 per cent and contained from 0.01 to 1.33 per cent of soluble copper. According to the manufacturers' statements, most of these materials contain inert diluents.

Table 1.—Chemical analyses of copper fungicides.

Sample	Probable Principal Copper Compound	Total Copper, Per Cent	Water-Soluble Copper, Per Cent
1	Unidentified	19.3	0.37
2	Unidentified	6.5	.02
3	Red cuprous oxide	49.9	1.33
4	Basic copper sulfate	14.1	.71
5	Basic copper sulfate	27.3	.38
6	Basic cupric carbonate	56.0	.08
7	Basic copper sulfate	27.6	.39
8	Basic copper sulfate	39.5	.11
9	Copper zeolite	28.8	.11
10	Copper oxychloride	24.4	1.05
11	Basic copper sulfate	37.3	.74
12[1]	Basic copper sulfate	25.6	.01
13	Copper phosphate	45.3	.03
14	Copper-zinc silicate	26.7	.13
15	Copper zeolite	30.8	.20
16	Basic copper sulfate	50.8	.18
17	Copper oxychloride	48.2	.38

[1] Bordeaux mixture, per cent total copper is that found in $CuSO_4 \cdot 5H_2O$ used to prepare bordeaux.

Three nicotine bentonite insecticides were employed with the copper fungicides.

Pertinent data relative to these materials are given below:

Nicotine bentonite A.—Tank-mix nicotine bentonite and soybean oil (Steiner & Sazama 1938), prepared to contain 5 pounds of bentonite, 1 pint of nicotine sulfate solution (40 per cent nicotine), and 1 quart of soybean oil to 100 gallons of spray mixture.

Nicotine bentonite B.—A factory-processed nicotine bentonite insecticide containing 4.74 per cent of nicotine alkaloid, lime (equivalent to 3.5 per cent calcium oxide), and a soap (not identified). Spray mixtures were prepared to contain nicotine equivalent to 1 pint of nicotine sulfate solution (40 per cent nicotine) to 100 gallons.

Table 2.—Effect of 1:2:100 bordeaux and various dilutions on tank-mix nicotine bentonite spray mixture.

STRENGTH	pH	WATER-SOLUBLE NICOTINE AS PER CENT OF TOTAL NICOTINE
None	7.5	9.4
1/32	8.4	18.5
1/16	8.9	24.4
1/8	9.8	48.6
1/4	11.5	54.7
1/2	12.0	65.3
Full	12.4	100.0

Nicotine bentonite C.—A factory-processed nicotine bentonite insecticide containing 13.8 per cent of nicotine alkaloid. Spray mixtures were prepared to contain the equivalent of 1 pint of nicotine sulfate solution (40 per cent nicotine) plus 2 pounds of bentonite to 100 gallons, according to the manufacturers' recommendation.

EXPERIMENTAL.—The rating of the compatibility of copper fungicides with nicotine bentonite insecticides for the purposes of this study is based on two criteria. First, the value of bentonite in the insecticide depends on the conversion of the greater part of the nicotine from the water-soluble nicotine sulfate to the water-insoluble nicotine bentonite. Therefore, any material that increases the quantity of water-soluble nicotine may be considered incompatible with nicotine bentonite insecticides. Second, copper fungicides normally contain a very small quantity, usually less than 1 per cent, of water-soluble copper. Any material that increases the water-soluble-copper content of a copper-fungicide spray mixture may be considered as incompatible with the copper fungicide. In these studies the effect of nicotine bentonite insecticides and copper fungicides on the quantities of water-soluble copper and nicotine developed in spray mixtures has been measured.

To demonstrate the effect of bordeaux mixture on the water-soluble nicotine content of nicotine bentonite sprays, there were prepared a series of sprays which consisted of 1:2:100 bordeaux mixture and various dilutions of this mixture. Table 2 shows the pH of these sprays and the percentage of nicotine in the water-soluble form.

As the strength of the bordeaux mixture was increased, both the pH value and the percentage of nicotine soluble in the water phase increased. These data show not only that the pH affects the quantity of water-soluble nicotine present in the nicotine bentonite-bordeaux spray, but also that even the minute quantity of free lime resulting from the most dilute bordeaux mixture has an appreciable effect on the solubility of nicotine in nicotine bentonite.

Four series of tests were planned to demonstrate the compatibility of copper fungicides with nicotine bentonite insecticides. The concentrations of fungicide and insecticide in the spray mixtures studied were adjusted to be equivalent to 0.25 pound of metallic copper and 1 pint of nicotine sulfate solution (40 per cent nicotine) to 100 gallons. The data from these tests are given in table 3.

In the first series of tests the pH and water-soluble copper of spray mixtures containing only the copper fungicide were determined. The pH of these mixtures ranged from 6.2 to 12.5, and the soluble-copper content from less than 0.2 (bordeaux mixture) to 8.9 p.p.m.

The second series of tests was made with spray mixtures of the several copper fungicides used in the first series plus bentonite employed at the rate of 5 pounds to 100 gallons. Except with the strongly alkaline fungicides (Nos. 4 and 12), the spray mixtures of bentonite with the fungicide showed an increase in pH over that found for the fungicide alone, but a great reduction in soluble-copper content. This result confirmed our theory that bentonite should reduce the soluble-

copper content of spray mixtures provided there are no complicating factors.

In the third series nicotine bentonite A was added to the several fungicides employed in the previous tests. The addition of nicotine bentonite A had the same effect, both on the pH of the spray mixture and on the soluble-copper content of all the fungicide mixtures, as had the addition of bentonite only. In each test the copper fungicide increased the soluble-nicotine content of the spray mixture.

mation of the findings of Kadow *et al.* (1938), nicotine bentonite B greatly increased the water-soluble copper in the spray mixture, the increase in sample 8 being 93 times.

Nicotine bentonite C, a manufacturer's experimental formula, was tested with only three of the copper fungicides. When used alone, this material had a pH of 6.8, and 42.8 per cent of the total nicotine was water-soluble. The addition of 2 pounds of bentonite, recommended by the manu-

Table 3.—Analyses of water phase of spray mixtures of copper fungicide and nicotine bentonite insecticide.

Copper Fungicide Sample No.	Series 1 Fungicide Alone		Series 2 Fungicide plus Bentonite Only		Series 3 Fungicide Plus Nicotine Bentonite A			Series 4 Fungicide Plus Nicotine Bentonite B		
	pH	Water-soluble copper, p.p.m.	pH	Water-soluble copper, p.p.m.	pH	Water-soluble copper, p.p.m.	Per cent of nicotine water-soluble	pH	Water-soluble copper, p.p.m.	Per cent of nicotine water-soluble
None	—	—	7.2	—	7.5	—	9.4	8.7	—	27.4
1	6.4	5.6	7.3	<0.2	7.4	<0.2	12.5	8.6	9.5	24.8
2	7.6	.3	7.7	< .2	7.9	< .2	17.0	8.6	8.5	27.4
3	7.0	4.4	9.1	.5	8.8	.9	36.9	9.1	38.5	35.3
4	11.9	8.9	11.7	.8	11.5	.7	100.0	10.6	19.1	93.3
5	7.3	3.1	7.7	< .2	7.7	1.2	16.0	8.7	12.2	33.0
6	7.2	<.2	7.7	< .2	7.8	< .2	10.8	8.7	9.5	26.4
7	7.5	1.0	7.9	< .2	7.7	< .2	16.5	8.6	15.0	31.6
8	7.6	<.2	8.0	< .2	7.9	< .2	16.5	8.7	18.6	30.8
9	7.2	.6	7.4	.4	7.7	< .2	10.4	8.6	6.9	25.3
10	7.7	2.5	8.0	.9	8.1	.9	17.2	8.7	13.8	27.4
11	6.9	2.7	7.6	< .2	7.6	< .2	13.7	8.6	17.5	26.4
12	12.5	<.2	12.3	< .2	12.4	< .2	100.0	12.3	6.1	97.6
13	6.2	1.3	7.7	< .2	7.5	< .2	10.2	8.6	2.8	24.8
14	7.4	.3	7.6	< .2	7.7	< .2	14.8	8.7	7.9	27.9
15	7.3	.6	7.7	< .2	7.7	< .2	11.3	8.7	12.0	22.9
16	6.8	1.2	7.6	< .2	7.7	< .2	11.5	8.7	7.7	25.3
17	7.1	1.3	7.7	< .2	8.0	< .2	13.4	8.8	27.7	24.6

The fourth series was the same as series 3 except that nicotine bentonite B (factory-processed) was substituted for nicotine bentonite A in the spray mixtures. The spray mixtures of the several copper fungicides with nicotine bentonite B showed similarly high pH values which, except for the strongly alkaline materials 4 and 12, were appreciably higher than those found in the other three series. As would be expected from the pH of these spray mixtures, there was in general a much greater percentage of water-soluble nicotine than in mixtures containing nicotine bentonite A. However, eight of the copper fungicides reduced the content of water-soluble nicotine below that found in nicotine bentonite B alone. In confir-

facturer, increased the pH to 7.4 and reduced the water-soluble nicotine to 11.3 per cent. The addition of copper fungicides 13 and 17 to the spray mixture of nicotine bentonite C plus bentonite had little or no effect on its water-soluble-nicotine content. The strongly alkaline fungicide 12 (bordeaux mixture) completely decomposed the nicotine bentonite compound, rendering the nicotine completely water-soluble. Nicotine bentonite C plus bentonite reduced the water-soluble copper content of the spray mixtures.

DISCUSSION.—Two of the copper fungicides studied, Nos. 4 and 12, were strongly alkaline, with pH values 11.9 and 12.5, respectively, and a third fungicide, No. 3,

increased in alkalinity greatly when used in combination with bentonite. All these materials greatly increased the water-soluble-nicotine content of the nicotine bentonite insecticides. The 14 remaining fungicides increased the soluble-nicotine content of nicotine bentonite A by only 0.8 to 7.8 per cent (of total nicotine), and 8 of them, Nos. 1, 6, 9, 11, 13, 15, 16, and 17, actually reduced the soluble-nicotine content of nicotine bentonite B. Excluding Nos. 3, 4, and 12, the fungicides had little effect on the soluble-nicotine content of nicotine bentonite sprays, which would probably be of negligible importance under field conditions.

Bentonite alone and the nicotine bentonite insecticides A and C were effective in reducing the soluble-copper content of the fungicide spray mixtures. It should be noted that uncombined bentonite was added to the spray tank in these instances. On the other hand, nicotine bentonite B increased the soluble-copper content of the fungicide sprays. This may be attributed to the processing of the nicotine bentonite or to added ingredients present in nicotine bentonite B which are not present in the other two insecticides.

Since the experiments reported herein represent a study of the water phase of spray mixtures, they cannot be accepted as indicating the effect of nicotine bentonite insecticides on the solubility of copper fungicides in spray residues. Nor do they in any way indicate the effect of copper fungicides on the insecticidal efficiency of the nicotine bentonite spray residues. The ultimate effect of mixing copper fungicides and nicotine bentonite insecticides on the water-soluble copper and nicotine contents of the spray residues will depend upon atmospheric conditions and on the chemical composition of the fungicide and insecticide used.

SUMMARY.—The effect of copper fungicides and nicotine bentonite insecticides on the water-soluble nicotine and water-soluble copper contents of the water phase of spray mixtures of these materials has been studied in the laboratory. The chemical analyses of 17 copper fungicides are reported. Preliminary experiments show that a 1/32:1/16:100 bordeaux mixture has a measurable effect on the water-soluble nicotine content of nicotine bentonite sprays. As the bordeaux concentration is increased there is a corresponding increase in the pH and the water-soluble nicotine content of the spray mixture.

Copper fungicides that produce strongly alkaline (above pH 8.5) spray mixtures, alone or in combination with nicotine bentonite insecticides, will result in a large increase in the soluble-nicotine content of nicotine bentonite spray mixtures.

Nicotine bentonite insecticides that contain or are used with unaltered bentonite reduce the soluble-copper content of the copper fungicide sprays. A factory-processed nicotine bentonite insecticide was found to increase the soluble-copper content of the fungicide spray mixtures.

These results apply only to spray mixtures and should not be interpreted as applying to spray residues.—3-30-42.

LITERATURE CITED

Kadow, K. J., S. L. Hopperstead and M. W. Goodwin. 1938. The relation of copper fungicides to lead arsenate-lime and fixed nicotine-oil sprays 1938 results. Trans. Peninsula Hort. Soc. **28**(5): 88–98.

Steiner, L. F., and R. F. Sazama. 1938. Experiments with tank-mix nicotine bentonite-soybean oil for codling moth control. JOUR. ECON. ENT. **31**(3): 366–74.

Steiner, L. F., and J. E. Fahey. 1939. The effects of neutral copper fungicides on tank-mix nicotine-bentonite in control of the codling moth. JOUR. ECON. ENT. **32**(3): 365–9.

CAPTAIN CARPENTER IN AFRICA

Dr. Stanley J. Carpenter, now a Captain in the Sanitary Corps of the U. S. Army, is at present in Africa on a special mission. He is in charge of a unit detailed to make original investigations on mosquitoes and the control of malaria. This information comes through Mrs. Carpenter, of Little Rock, Arkansas. The exact location in Africa is not divulged.

LIEUTENANT HORACE O. LUND

Dr. Horace O. Lund of Athens, Georgia, who has taught entomology in the Division of Biological Sciences of the University of Georgia since 1936, has been commissioned Lieutenant, Junior Grade, in the United States Navy, and is stationed at the Marine Barracks, Mumford Point, New River, North Carolina.

Laboratory Fumigations of the California Red Scale with Methyl Bromide, Alone and with Hydrocyanic Acid

HAROLD R. YUST, R. L. BUSBEY, and L. B. HOWARD,[1] *U. S. Department of Agriculture, Bureau of Entomology and Plant Quarantine*

Methyl bromide is now widely used as a fumigant against insects, especially in suitable chambers of nursery stock and in railroad cars of fruits and vegetables which are to be moved from areas where quarantines have been established for the Japanese beetle, the white-fringed beetle, etc. Numerous reports have been published on its use, but no extensive tests against the California red scale *Aonidiella aurantii* (Mask.) have been reported. Mackie & Carter (1937) stated that they obtained a complete kill of resistant red scale with this fumigant, and Quayle (1938) referred to fumigations of resistant and nonresistant strains of the red scale with methyl bromide in a study of resistance to hydrocyanic acid. It has been used to some extent in southern California against red scale infestations on citrus nursery stock in preparation for movement into other areas.

This paper is based on laboratory fumigations made to obtain information on the effectiveness of methyl bromide as a fumigant of the California red scale. Insects in different stages of development were exposed to various concentrations of methyl bromide for different periods and different temperatures, and to combinations of hydrocyanic acid and methyl bromide.

APPARATUS AND PROCEDURE.—The fumigations were made in a gastight chamber having a capacity of 700 liters. Liquid methyl bromide was measured into the chamber from a burette provided with a jacket, through which ice water was circulated. Throughout the fumigations the gas in the chamber was circulated constantly. An approximately constant temperature of 77° F. and a relative humidity of 65 per cent were used in each fumigation unless otherwise stated.

Resistant scales (comparatively difficult to kill with hydrocyanic acid) were used in the fumigations and were reared in the laboratory on lemon fruits at the above temperature and relative humidity unless otherwise stated. Following fumigation the insects were held at the rearing temperature and relative humidity, except in the temperature-mortality experiment. The insects that were reared on any one lemon fruit were all of the same age (in days). In nearly all the experiments the scales were selected before fumigation and encircled with ink. Either 25 or 50 insects in one or two stages were marked on each lemon fruit. Only female insects were tested, except in the first stage and early second stage, when the sexes are not distinguishable.

The insects that were killed by methyl bromide were very slow to develop visible characteristics of death, and in most experiments in which the mortality was approximately 50 per cent the dead and live insects could not be distinguished with any degree of certainty 2 weeks after fumigation, because of considerable delayed mortality. This also has been found true of certain other insects by Mackie & Carter (1937) and Piper & Davidson (1938). The mortality counts in these experiments were made not sooner than 18 days after fumigation and in most cases not until 3 or 4 weeks after fumigation. By this time a large proportion of the survivors in the tests of immature stages had developed to another stage or, in the tests of mature females, had begun reproducing.

REACTION OF DIFFERENT DEVELOPMENTAL STAGES.—Preliminary experiments indicated that the reaction of certain developmental stages of the red scale to methyl bromide was different from their reaction to hydrocyanic acid. Consequently, the relative susceptibility of the developmental stages of the female scales was determined. Insects of all stages,[2] ranging in age from 2 to 54 days,

[1] Now with the Bureau of Agricultural Chemistry and Engineering.

[2] It has been found necessary to define the terms applied to certain visible changes in the developmental periods of the red scale which are associated with marked differences in susceptibility to fumigation with hydrocyanic acid. The early first stage is used in this paper to designate the insects of both sexes from the time they emerge as crawlers until about midway in the first stage, when the body has flattened and become attached to the scale covering in preparation for molting. Scales in the remainder of the first stage, until this molt has been completed, are designated as in the first molt. In a similar way female scales in the

were fumigated with concentrations of 40, 60, 80, and 120 mg. per liter for 40 minutes.

From these preliminary tests it was concluded that the scales in the early second stage, the early gray adult, and the reproducing mature adult were most difficult to kill. Scales in the first stage were more susceptible than those in the early second stage. Scales in the second molt were relatively easy to kill. This is especially significant, because under most conditions scales are more difficult to kill with hydrocyanic acid at this time than at any other. There was also considerable variation in the kill of scales at different ages of the same developmental stage.

CONCENTRATION-MORTALITY TESTS.—Scales in the early gray adult stage (25 days old) were fumigated with four concentrations for 40 minutes, 400 insects being treated at each concentration in each of three replications. Fifty insects were selected on each lemon. The concentrations were 60, 70, 80, and 90 mg. per liter and the corresponding mortalities were 15.1 ± 1.0, 61.9 ± 2.5, 96.1 ± 0.9, and 99.75 ± 0.18 per cent. Corrections were made for natural mortality of 2.5 per cent.

Scales of all developmental stages on lemon fruits from the field were treated with concentrations of 30 and 40 mg. per liter for 3 hours on January 18, 1939, to determine if complete mortality would be obtained. The scales were preconditioned for about 20 hours at 77° F. and a relative humidity of approximately 65 per cent (the temperature and relative humidity at which the fumigations were made). Twenty-seven days after fumigation all the insects were inspected for survivors. A total of 17 live mature females were found on 12 of the 36 lemons treated with a concentration of 30 mg. per liter. No surviving scales were observed on any of the 36 lemons treated with a concentration of 40 mg. per liter.

Four additional 3-hour fumigations of scales from the field were made on May 26, 1939, two at 59° F. with concentrations of 60 and 70 mg. per liter and two at 77° F. with concentrations of 30 and 40 mg. per liter. The scales were preconditioned for 4 hours at the treatment-temperature, and those fumigated at 59° F. were held at that temperature for 4 hours after treatment and then placed in a constant temperature of 77° F. along with those fumigated at that temperature. There were 48 lemons in each fumigation. When the scales were inspected for survivors 4 to 5 weeks later, it was observed that a complete kill had been obtained in all four fumigations. The better kill in this test at 30 mg. per liter than in the preceding test may be due to the generally higher field temperatures in May than in January.

TIME-MORTALITY TESTS.—Scales in the early gray adult stage (25 days old) were exposed for four lengths of time to a concentration of 20 mg. per liter, 200 insects being included for each exposure time in each of six replications. Fifty insects were tested per lemon. The exposures were 120, 140, 160, and 180 minutes, and the corresponding mortalities were 36.5 ± 2.4, 87.7 ± 1.6, 98.8 ± 0.4, and 100 per cent. Corrections were made for a natural mortality of 2.5 per cent.

Although there was complete mortality of the marked insects in the 180-minute exposure over a month after fumigation, there were survivors among the unmarked scales.

TEMPERATURE-MORTALITY TESTS.—Some idea of the influence of temperature on the effectiveness of methyl bromide was obtained in tests with a concentration of 70 mg. per liter for 40 minutes at temperatures of 50°, 63.5°, and 77° F. The insects were mature females 38 days old. Fifty insects on each of 24 lemons were fumigated at each temperature. Those fumigated at 50° and 63.5° F. were preconditioned at these temperatures for 7 and 8 hours, respectively, before fumigation. After fumigation the scales in these two groups were held at the fumigation temperature for 5 hours before being removed to a constant temperature of 77° F., where they remained until counted. The mortalities for the above three temperatures in the order named were 16.4 ± 1.6, 42.3 ± 2.1, and 99.5 ± 0.2 per cent. No corrections were made for natural mortality, which was less than 1 per cent at all temperatures.

Fisk & Shepard (1938), Hawkins (1938), and Mackie (1937) also observed a reduction in kill at low temperatures in

second stage may be considered as in the early second stage and in the second molt, but in the case of the males this entire period is called the second stage. The males were not included in these tests after they became distinguishable from the females midway in the second stage. Female scales are called gray adults from the end of the second molt until fertilization takes place, and mature females following fertilization.

methyl bromide fumigations of other insects.

COMBINATIONS OF HYDROCYANIC ACID AND METHYL BROMIDE.—The relative effectiveness of hydrocyanic acid alone and a mixture of hydrocyanic acid and methyl bromide was observed in an experiment that was duplicated on two successive days using mature female scales 33 days old, as shown in table 1. The exposures were for 40 minutes, and 600 insects (50 per lemon) were in each fumigation on each day.

cyanic acid appeared to protect the scales in the late second molt and early gray adult stages against hydrocyanic acid. Protection of the scales against hydrocyanic acid by other gases was previously observed at the Whittier laboratory.[1] The kill of scales in the second molt with hydrocyanic acid alone was higher than that of the early gray adults, probably because the former were greatly retarded in development.

In another experiment two groups of scales were fumigated with concentra-

Table 1.—Results of fumigation experiments with hydrocyanic acid and with combinations of hydrocyanic acid and methyl bromide against several stages of the California red scale.[1]

Fumigant	Concentration of Fumigants, Mg. per Liter		Average Per Cent Mortality		
	Hydrocyanic acid	Methyl bromide	Scales in late second molt	Early gray adults	Mature females
Hydrocyanic acid alone	0.9	—	75.8±0.7	64.9±3.9	—
	0.6	—	—	—	68.4±1.6
Hydrocyanic acid and methyl bromide	0.9	10.0	87.5±0.6	89.4±1.7	—
	0.6	20.0	—	—	86.6±1.2
Methyl bromide followed by hydrocyanic acid	0.9	10.0	67.0±1.2	49.6±2.8	—

[1] The methyl bromide concentrations alone gave no kill.

In another experiment, the results of which are also included in table 1, scales in the early gray adult and late second molt stages (both 25 days old) were exposed (1) to hydrocyanic acid alone, (2) to a mixture of hydrocyanic acid and methyl bromide, and (3) to methyl bromide followed by hydrocyanic acid. In the fumigations with hydrocyanic acid alone and with the mixed gases the exposure was 40 minutes, but in the fumigation with methyl bromide followed by hydrocyanic acid the insects were exposed to methyl bromide for only 10 minutes and then held for 8 minutes before the regular 40-minute exposure to hydrocyanic acid. In each exposure there were 16 lemons, and 50 insects in the early gray adult stage and 25 insects in the late second molt stage were marked on each lemon.

In all stages a mixture of the two gases gave a better kill than hydrocyanic acid alone. Methyl bromide followed by hydrocyanic acid[1] was the most effective treatment.

tions of hydrocyanic acid and methyl bromide that would give approximately the same kills and a third group was fumigated with a mixture of half of each component. Scales in the gray adult stage (half 24 and half 25 days old) and mature female scales (half 35 and half 36 days old) were fumigated as indicated in table 2. The scales were reared at a constant temperature of 77° F. and a relative humidity of 65 per cent. The treatments were also at the same temperature and relative humidity. Each mortality figure is based on 1200 insects on 24 lemon fruits (50 scales per fruit).

Under the conditions prevailing in this experiment there was a synergistic action on the gray adult scales and an antagonistic action on the mature females. These results were verified in other similar experiments. The difference in the reaction of two developmental stages of the

[1] A sublethal dosage of hydrogen sulfide followed by hydrocyanic acid resulted in an increase in survival.

Table 2.—Results of fumigation with hydrocyanic acid and methyl bromide alone and in combination, against the California red scale in the gray adult and mature female stages.

Treatment	Gray Adult			Mature Female		
	Concentration, Mg. per Liter			Concentration, Mg. per Liter		
	Hydrocyanic acid	Methyl bromide	Per cent mortality	Hydrocyanic acid	Methyl bromide	Per cent mortality
Hydrocyanic acid	1.16	—	76.2±1.9	0.90	—	96.7±0.8
Methyl bromide	—	70.0	51.8±1.5	—	60.0	96.4±0.8
Hydrocyanic acid and methyl bromide	0.58	35.0	96.8±0.8	0.45	30.0	90.1±1.1

same insect suggests the importance of studying more than one stage in insecticide tests. In a patent granted V. A. Johnson (1939)for using a combination of methyl bromide and hydrocyanic acid, it was stated that a mixture has a synergistic action on such insects as Japanese beetle adults.

INJURY TO FRUIT.—No injury to the lemons appeared in any of these experiments.

SUMMARY.—To obtain information on the efficacy of methyl bromide as a fumigant of the California red scale, fumigations were made in the laboratory under controlled conditions.

Female scales of all developmental stages and many different ages were fumigated. The insects were on lemons in all cases and no injury to the lemons resulted in any of the fumigations.

The insects killed by methyl bromide fumigation were slower to develop visible characteristics of death than were those killed by hydrocyanic acid fumigation.

Scales in the early second stage, early gray adults, and mature females were most difficult to kill. Scales in the second molt, which are especially difficult to kill with hydrocyanic acid fumigation, were killed relatively easily with methyl bromide fumigation.

Complete mortality was obtained upon fumigation with a methyl bromide concentration of 40 mg. per liter for 3 hours at a constant temperature of 77° F. A concentration that gave 99.5 per cent kill of mature female scales at 77° F. gave only a 16.4 per cent kill at 50° F.

Fumigation with a mixture of hydrocyanic acid and methyl bromide resulted in a synergistic action on the scales in the gray adult stage and an antagonistic action on the mature female scales. The difference in the reaction of two developmental stages of the same insect suggests the importance of studying more than one stage in insecticide tests.

Prefumigation with a sublethal dosage of methyl bromide reduced the kill of the California red scale produced by hydrocyanic acid.—3-13-42.

LITERATURE CITED

Fisk, Frank W., and Harold H. Shepard. 1938. Laboratory studies of methyl bromide as an insect fumigant. JOUR. ECON. ENT. **31**(1): 79–84.

Hawkins, Lon A. 1938. Fumigation of dormant deciduous nursery stock for the oriental fruit moth with methyl bromide. U. S. Dept. Agr., Bur. Ent. & Plant Quar., E-458.

Johnson, V. A. 1939. Fumigating with hydrocyanic acid and methyl bromide. U. S. Patent 2,147,947; issued Feb. 21.

Mackie, D. B., and W. B. Carter. 1937. Methyl bromide as a fumigant. A preliminary report. Calif. Dept. Agr. Bul. **26**(2): 153–62.

Mackie, D. B. 1937. Entomological service. Calif. Dept. Agr. Bul. **26**(4): 418–38.

Piper, W. R., Jr., and R. H. Davidson. 1938. Methyl bromide vapor against five species of stored product insects. JOUR. ECON. ENT. **31**(3): 460–1.

Quayle, H. J. 1938. The development of resistance to hydrocyanic acid in certain scale insects. Hilgardia **11**(5): 183–210.

Insecticidal Action of Some Pyrrolines and Pyrrolidines on *Thermobia domestica*[1]

J. G. KIRCHNER[2] and CHARLES H. RICHARDSON, *Iowa State College, Ames*

Nicotine, an important member of the nitrogen heterocyclic series of compounds, has long been a center of insecticidal interest. Tattersfield (1927) and Tattersfield & Gimingham (1927) concluded from studies of nicotine and certain related compounds that the nicotine molecule owes its high insecticidal potency to its make-up as a whole although the attachment of the pyrrolidine nucleus in the β-position of the pyridine ring and the presence of an asymmetric carbon atom were considered of possible significance. From an investigation of metanicotine and dihydronicotine Harlan (1928) concluded that the greater part of the toxicity of nicotine lay in the methylpyrrolidine nucleus. LaForge (1928a, 1928b) prepared and Richardson & Shepard (1930) investigated a series of pyridine and pyrrolidine derivatives in an attempt to explain the unique toxicity of nicotine. None of the considerable number of compounds tested equaled nicotine in toxicity to *Aphis rumicis* L., although a marked superiority of N-methylpyrrolidine over pyridine was established.

Meanwhile, investigation of a large group of pyridyls, dipiperidyls and pyridylpiperidines (Smith *et al.* 1930), resulting in the synthesis of neonicotine (*dl*-β-pyridyl-α-piperidine), demonstrated that certain pyridine derivaties in which piperidine is substituted for N-methylpyrrolidine closely approach nicotine in toxicity to *Aphis rumicis*. Disclosure of the structural identity of neonicotine and anabasine (*l*-β-pyridyl-α-piperidine) (Smith 1932), and demonstration of the high insecticidal action of the latter compound (see Roark 1941) leave little doubt of the importance of the β-position in the pyridine ring but indicate that the piperidine ring can be substituted for N-methylpyrrolidine with slight loss of toxicity.

Returning again to the N-methylpyrrolidine nucleus: Craig & Richardson (1933) examined a series of α-substituted N-methylpyrrolidines in which the negativity of the radicals substituted for pyridine, as measured by the dissociation constants of the compounds, varied within the limits of 10^{-4} and 10^{-6}. Nicotine was the most toxic and negative of these compounds while the substituted hydrogen, methyl and ethyl derivatives were among the least toxic and negative. Later studies (Richardson *et al.* 1936) on the nornicotines, which are identical in structure with nicotine except for the absence of a methyl group on the nitrogen of the pyrrolidine nucleus, proved that *dl*-β-nornicotine was equal to nicotine in toxicity to *Aphis rumicis*. The recent work of Hansberry & Norton (1940) confirms this view. A methyl group in this position is, therefore, not essential for high toxicity in the pyridyl-pyrrolidine molecule.

The effect of optical isomerism on the insecticidal action of N-heterocyclic compounds has also received some attention. Mayor's early paper (1904) which showed that *d*-nicotine is about one-half as toxic as *l*-nicotine to vertebrate animals furnished a stimulus for work on insects with nicotine and related compounds. Several investigations with *Aphis rumicis* as the test insect, reveal that *dl*-nicotine is approximately one-half as toxic as *l*-nicotine, and that *d*-nicotine is considerably less toxic than the latter compound (Craig & Richardson 1933; Richardson *et al.* 1936; Hansberry & Norton 1940). In comparison, *l*-nornicotine, *d*-nornicotine, *dl*-nornicotine are about equally toxic, and all of them are more toxic than *l*-nicotine. Anabasine, the naturaly occuring *l*-neonicotine, is probably somewhat more toxic than *dl*-neonicotine (Richardson *et al.* 1936). On the other hand, the acid tartrates of *d*- and *l*-α-p-tolylpyrrolidine require approximately equal concentrations for 50 per cent mortality of *Aphis rumicis;* but at higher concentrations the *levo* isomer appears considerably more toxic (Starr & Richardson 1936). Chemical difficulties of preparing optical isomers have restricted advancement in this important field.

In view of the foregoing facts it seemed pertinent to examine a series of α-substi-

[1] Journal paper No. J-982 of the Entomology and Economic Zoology Section, Iowa Agricultural Experiment Station, Ames. Project No. 137. This research was supported in part by the Industrial Science Research Fund of Iowa State College.

[2] Formerly Research Fellow in chemistry, Iowa State College; now Hawaiian Pineapple Association Fellow in Bio-Organic Chemistry at the California Institute of Technology, Pasadena.

Table 1.—Comparative toxicity of certain alpha-substituted pyrrolines and pyrrolidines.

Compound	Concns. in Gm. per 100 cc. Solution	No. of Insects Used	Range in Mortality, Per Cent	Mean Mortality Per Cent	Median Lethal Concentration Grams per 100 cc.
l-β-pyridyl-α-*N*-methyl-pyrrolidine (nicotine)	.1	40	0–10	5	
	.2	80	30–70	44.2	
	.3	50	20–70	48	
	.4	30	70–100	86.6	
	.5	90	60–100	84	
	1.0	40	—	100	0.27±0.02[1]
2-Mesityl-α-pyrroline	.5	30	0–30	20	
	.7	30	30–40	36.6	
	1.0	40	40–70	57	
	1.5	20	—	90	
	2.0	20	—	100	
	4.0	10	—	100	.84±.10
2-Mesityl-α-pyrrolidine	.5	20	0–10	5	
	.6	50	0–30	8	
	.7	50	10–40	26	
	1.0	50	40–70	58	
	1.25	30	—	80	
	1.5	50	50–90	78	
	2.0	20	—	100	.97±.07
l-α-Cyclohexylpyrrolidine	.5	20	—	0	
	.7	40	0–30	17.5	
	.8	20	30–40	35	
	1.0	40	50–60	57	
	1.5	30	80–90	83	
	2.0	20	—	90	
	3.5	10	—	100	1.00±.10
d-α-Cyclohexylpyrrolidine	.5	20	0–10	10	
	.7	40	0–30	15	
	.8	20	20–30	25	
	1.0	40	40–70	57	
	1.5	30	70–80	73	
	2.0	20	90–100	95	1.02±.11
α-Cyclohexylpyrroline	.5	20	—	0	
	.7	30	10–20	16	
	.8	20	20–30	25	
	1.0	40	30–80	55	
	1.5	30	60–80	66	
	2.0	20	90–100	95	
	4.0	10	—	100	1.08±.10
α-Thienyl-α-pyrrolidine	.5	10	—	0	
	.75	30	0–10	6.6	
	1.0	50	20–50	34	
	1.5	50	—	60	
	1.6	40	70–80	75	
	1.75	40	90–100	97.5	
	2.0	20	—	100	
	4.0	10	—	100	1.22±.08
l-α-Phenylpyrrolidine	.7	40	0–10	5	
	1.0	50	20–40	30	
	1.3	40	20–50	35	
	1.4	50	—	40	
	1.5	50	50–80	58	
	1.7	40	—	80	
	2.0	30	—	90	
	4.0	10	—	100	1.31±.09

Table 1.—Comparative toxicity of certain alpha-substituted pyrrolines and pyrrolidines—*Cont.*

Compound	Concns. in Gm. per 100 cc. Solution	No. of Insects Used	Range in Mortality Per Cent	Mean Mortality Per Cent	Median Lethal Concentration Grams per 100 cc.
d-α-Phenylpyrrolidine	.7	40	0–10	5	
	1.0	50	0–30	20	
	1.3	30	—	20	
	1.4	50	—	40	
	1.5	40	60–90	75	
	2.0	30	80–100	90	
	4.0	10	—	100	1.33±.09
α-n-Butylpyrroline	.5	20	10–20	15	
	.7	30	0–10	7	
	1.0	40	20–50	27	
	1.5	20	50–60	55	
	2.0	40	60–80	70	
	2.5	20	90–100	95	
	4.0	10	—	100	1.36±.17
α-Phenylpyrroline	.5	20	—	0	
	.7	40	0–20	15	
	1.0	40	10–50	25	
	1.5	40	40–60	50	
	2.0	40	40–100	77	
	2.5	20	—	90	
	3.0	10	—	100	1.37±.21
α-Thienyl-α-pyrroline	.5	20	—	0	
	.8	40	10–30	17	
	1.0	50	10–40	28	
	1.5	40	30–80	55	
	2.0	50	60–90	74	1.39±.16
dl-α-Cyclohexylpyrrolidine	.5	40	0–10	5	
	.7	40	0–50	10	
	1.0	60	10–30	21	
	1.5	40	30–50	37	
	2.0	40	70–100	95	
	4.0	30	90–100	96	
	8.0	10	—	100	1.46±.16
α-n-Butylpyrrolidine	1.0	30	—	0	
	1.5	50	20–40	30	
	2.0	50	40–60	50	
	2.5	50	70–100	86	
	3.0	20	—	90	
	4.0	10	—	100	1.92±.15
dl-α-Phenylpyrrolidine	.5	20	0–10	5	
	1.0	40	0–30	7	
	1.5	40	0–30	17	
	2.0	50	40–60	50	
	2.5	40	60–70	63	
	3.0	30	90–100	95	
	4.0	10	—	100	1.99±1.3

[1] The limits (1.96×the standard error of the median lethal concentration) correspond with odds of 19 in 20.

tuted pyrrolines and pyrrolidines, and to include, in so far as possible, the optical isomers.

The insecticidal part of the investigation was completed at Ames, Iowa, between September 1937 and June 1939.[1]

MATERIALS.—The 14 compounds which were compared with nicotine in this

[1] A brief summary of the results of this investigation has been published by Kirchner (1939). In the present article the experimental data are analyzed statistically and the results are discussed in the light of certain information which recently became available.

study were prepared in the laboratory. α-Thienyl-α-pyrroline, a white crystalline solid melting at 57° C., and 2-mesityl-α-pyrroline, a colorless, rather unstable liquid which turns a dark red color on standing in air and boils at 101–102° C. (2 mm.) were prepared for the first time. α-Thienyl-α-pyrrolidine, a liquid boiling at 88–89° C. (3 mm.) and 2-mesityl-α-pyrrolidine, a liquid boilding at 124.2° C. (3.5 mm.), were obtained by reduction of the corresponding pyrrolines. Methods of preparing these compounds have already appeared (Kirchner & Johns 1940). The phenyl-, n-butyl- and cyclohexylpyrrolines were prepared by the methods of Bulbrook,[1] Craig (1934) and Starr *et al.* (1932); and the corresponding pyrrolidines were obtained from these compounds by reduction with sldium and alcohol. Only the optical isomers of α-phenylpyrrolidine and α-cyclohexylpyrrolidine could be obtained; attempts to resolve the isomers of the other compounds failed (Kirchner & Johns 1940). Most of these compounds are rather sparingly soluble in water.

The nicotine used in these experiments was a redistilled product of high purity.

The firebrat, *Thermobia domestica* (Packard) was selected as the test insect because of its rather marked resistance to many poisons as compared with *Aphis rumicis*, and the greater ease with which it can be reared and handled. The insects were cultured in a constant temperature chamber at 38° C. and relative humidity of approximately 70 per cent.

METHODS.—All of the compounds were applied as contact sprays by means of a modified Tattersfield apparatus (Craig & Richardson 1933). The spraying pressure was maintained at 9 pounds per square inch and the atomizer nozzle directed the spray on the center of a crystallizing dish 10 cm. in diameter which held the insects. Small and reproducible quantities of liquid could be sprayed into the dish with this apparatus.

Because most of the compounds are slightly soluble in water, they were made up in solutions that contained 50 per cent by volume of acetone. The acetone so lowered the surface tension that the addition of a spreading and wetting agent was unnecessary; the possible toxic effect of a spreader in the solutions was thus avoided. A 50 per cent acetone solution had no toxic effect on the firebrat.

Ten insects not less than 7 mm. in length were used in each test. In making a test, the insects were placed on a filter paper in the crystallizing dish, the reservoir of the spraying apparatus was filled with 1 cc. of the test solution, and the compressed air was turned on. As soon as the atomizer was emptied, the dish was removed from the apparatus and allowed to stand for 2 minutes when the insects became quiet enough for convenient handling. The insects were then transferred to a petri dish lined with filter paper by inverting the spraying receptacle over the petri dish. From this dish the insects were removed to individual containers and supplied with food.

Mortality counts were made at the end of 24 hours because test runs indicated no variation in the count over a period of 48 hours. All paralyzed insects were considered as dead.

Stock solutions of each compound were made up to contain 4 grams per 100 cc. of solution, and from these the solutions of lower concentration were obtained by dilution. The concentrations which gave mortalities that fell in the central part of the mortality curve were tested from 4 to 6 times, higher or lower concentrations from 1 to 3 times. Replication of tests was restricted by the small quantities of the compounds available.

RESULTS.—The experimental data are presented in table 1, together with the median lethal concentrations in grams per 100 cc., and their limits corresponding with odds of 19 in 20 (column 6). The median lethal concentrations and their limits were calculated from logarithmic-probability curves by the small-sample method of Bliss (1938). These concentrations differ little from those derived from curves fitted by eye to the experimental data; but the limits obtained from the calculated standard errors of the median lethal concentrations have permitted a statistical estimation of the relative effectiveness of the compounds.

DISCUSSION.—In table 1, the compounds are arranged in decreasing order of their toxic action on the firebrat as based on the median lethal concentrations. Four distinct groups of compounds can be recognized: a group of highest toxicity oc-

[1] Unpublished thesis, Iowa State College Library, H. Bulbrook, 1935.

cupied alone by nicotine; a group of lowest toxicity in which are found α-n-butylpyrrolidine and *dl*-α-phenylpyrrolidine; and 2 groups of intermediate toxic value. The intermediate group of highest toxicity contains the 4 compounds, 2-mesityl-α-pyrrolidine to α-cyclohexylpyrroline. Between this group and nicotine lies 2-mesityl-α-pyrroline. It is probably not significantly distinct from the 3 most toxic members of the group just mentioned; nevertheless, its median lethal concentration is the smallest save that of nicotine in the series. Like nicotine, 2-mesityl-α-pyrroline colors rapidly in air owing probably to the unsual reactivity of the C-N bond;[1] and it is possible that this reactivity accounts for its position with respect to nicotine in the present series. Except for the thienyl compounds, the pyrrolines are more toxic than the corresponding racemic pyrrolidines.

The intermediate group of lower toxicity contains the compounds *l*-α-phenylpyrrolidine to *dl*-α-cyclohexylpyrrolidine separated from the intermediate group first mentioned by the compound, α-thienyl-α-pyrrolidine.

From the above considerations, the 2-mesityl radical ($2,4,6(CH_3)_3C_6H_2$-) is the most effective substituent. Relatively little difference is evident between the thienyl, phenyl and n-butyl radicals; however, the linkage of the last two radicals with pyrrolidine resulted in compounds of least toxicity in the series.

Among the optical isomers, the *levo* and *dextro*-cyclohexylpyrrolidines were identical or closely similar in toxicity as were also the *levo* and *dextro*-phenylpyrrolidines. The racemic compounds were significantly less toxic than their respective optical isomers. This was an unexpected result for it agrees neither with the situation in nicotine in which the *levo*, *dextro* and racemic forms differ markedly in toxicity from one another, nor with the situation in nornicotine in which the optical isomers and the racemic compound are essentially alike in toxicity.

The α-substituted pyrrolines and pyrrolidines produced a type of physiological action which has frequently been obtained with nicotine. During application of the spray, the insects remained motionless; but soon afterwards a period of intense excitement set in, followed later by a period of depression. Among the paralyzed insects, at the close of 24 hours, some exhibited paralysis of the forelegs and others paralysis of one side which caused them to describe a circular path when in motion.

SUMMARY.—Fourteen α-substituted pyrroline and pyrrolidine derivatives were tested in the laboratory in comparison with nicotine as contact insecticides against the firebrat.

The calculated median lethal concentrations place these compounds in the following decreasing order of toxicity: *l*-α-pyridyl-α-N-methylpyrrolidine (nicotine), 2-mesityl-α-pyrroline, 2-mesityl-α-pyrrolidine, *l*-α-cyclohexylpyrrolidine, *d*-α-cyclohexylpyrrolidine, α-cyclohexylpyrroline, α-thienyl-α-pyrrolidine, *l*-α-phenylpyrrolidine, *d*-α-phenylpyrrolidine, α-n-butylpyrroline, α-phenylpyrroline, α-thienyl-α-pyrroline, *dl*-α-cyclohexylpyrrolidine, α-n-butylpyrrolidine, *dl*-α-phenylpyrrolidine.

2-Mesityl-α-pyrroline, like nicotine, is somewhat unstable in air owing probably to the reactivity of the C-N bond. This reactivity may account for its relatively high toxicity. A tendency was noticed for most of the pyrrolines to be more toxic than the corresponding pyrrolidines.

l- and *d*-α-cyclohexylpyrrolidine and *l*-*d*-α-phenylpyrrolidine were mutually identical or very similar in toxic action; but each pair of optical isomers was significantly more toxic than its respective racemic compound. These 2 compounds differ markedly from nicotine and nornicotine with respect to the relation between optical isomerism and toxicity to insects.

The physiological action of these compounds on the firebrat resembles that frequently observed for nicotine.—3-6-42.

[1] Unpublished thesis: Iowa State College Library, L. C. Craig, 1931 and W. R. Harlan, 1928.

LITERATURE CITED

Bliss, C. I. 1938. The determination of the dosage-mortality curve from small numbers. Quart. Jour. Pharm. Pharmacol. **11**: 192–216.

Craig, L. C. 1934. Synthesis of α-nicotine and α-nornicotine. Jour. Am. Chem. Soc. **56**: 1144–7.

Craig, L. C., and C. H. Richardson. 1933. Insecticidal action in the nirogen heterocyclic compounds. Iowa State Coll. Jour. Sci. **7**: 477–86.

Hansberry, Roy, and L. B. Norton. 1940. Toxicities of optically active nicotines and nornicotines to *Aphis rumicis*. JOUR. ECON. ENT. **33:** 734–5.
Kirchner, J. G. 1939. Insecticidal action of some substituted pyrrolidines. Iowa State Coll. Jour. Sci. **14:** 53–4.
Kirchner, J. G., and I. B. Johns. 1940. Electron-sharing ability of organic radicals. XI. α-Thienyl- and α-mesityl-pyrrolidines. Jour. Am. Chem. Soc. **62:** 2183–4.
LaForge, F. B. 1928a. The preparation of some pyrrolidine derivatives. Jour. Am. Chem. Soc. **50:** 2471–7.
LaForge, F. B. 1928b. The preparation and properties of some new derivatives of pyridine. Jour. Am. Chem. Soc. **50:** 2477–83.
Mayor, A. 1904. In Pictet, A., and A. Rotschy. Synthese des nicotins. Ber. deutsch. Chem. Ges. **64:** 266–74.
Roark, R. C. 1941. A review of information on anabasine. U. S. Dept. Agr. Bur. Ent. & Plant Quar. Circ. E-537.
Richardson, C. H., L. C. Craig and T. R. Hansberry. 1936. Toxic action of nicotines, nornicotines and anabasine upon *Aphis rumicis* L. JOUR. ECON. ENT. **29:** 850–5.
Richardson, C. H., and H. H. Shepard. 1930. The insecticidal action of some derivatives of pyridine and pyrrolidine and of some aliphatic amines. Jour. Agr. Res. **40:** 1007–15.
Smith, C. R. 1932. Identity of neonicotine and the alkaloid anabasine. Jour. Am. Chem. Soc. **54:** 397–9.
Smith, C. R., C. H. Richardson and H. H. Shepard. 1930. Neonicotine and certain other derivatives of the dipyridyls as insecticides. JOUR. ECON. ENT. **23:** 863–7.
Starr, D. F., H. Bulbrook and R. M. Hixon. 1932. Electron-sharing ability of organic radicals. VI. Alpha-substituted pyrrolines and pyrrolidines. Jour. Am. Chem. Soc. **54:** 3971–6.
Starr, D., and C. Richardson. 1936. Toxicity of dextro and levo-alpha-paratolylpyrrolidine to *Aphis rumicis* L. JOUR. ECON. ENT. **29:** 214–5.
Tattersfield, F. 1927. The relationship between the chemical constitution of organic compounds and their toxicity to insects. Jour. Agr. Sci. **17:** 181–208.
Tattersfield, F., and C. T. Gimingham. 1927. Studies on contact insecticides. V. The toxicity of the amines and N-heterocyclic compounds to *Aphis rumicis* L. Ann. Applied Biol. **14:** 217–39.

Ovicidal Value of Light Mineral Oils for the Codling Moth[1]

R. L. WEBSTER and ELMER C. CARLSON, *Washington Agricultural Experiment Station, Pullman, Washington*

Most petroleum oils used for spraying fruit trees in the Pacific Northwest range in viscosity from 50 seconds Saybolt to 110 seconds. During the dormant season, only the heavy fractions (viscosity 110–120) are used. Such oils are but slightly refined, since there is little danger at that time of their use resulting in injury to fruit or foliage.

The lighter fractions, having a viscosity from 50 to 70, are generally used on foliage. Most of these are highly refined, with an unsulfonatable residue of 85 to 90 or higher. Spray oils with an unsolfonatable residue of less than 85 have come into use, largely because of their lower cost, although the danger of injury to fruits and foliage serves to limit their application. In the second and third cover sprays, a mineral oil is added to the usual mixture of lead arsenate and fungicide and serves as an ovicide for the codling moth at that time.

The use of oil later in the season has been complicated by the fact that residue removal is generally made more difficult (Overley, *et al.* 1937). On this account there has been a tendency to use the lighter fractions at lower concentrations but at more frequent intervals. Little information has been available concerning the efficiency in codling moth control of these light oils at low concentrations, therefore the experimental program at Wenatchee during the last 2 years has included a series of investigations to determine the value of these light oils as ovicides in the codling moth control program.

Throughout the years the Washington Agricultural Experiment Station has been attempting to determine the value of various petroleum oils as ovicides for the codling moth the following procedure has been employed. Moths are reared in large numbers, induced to deposit eggs on apples brought into the laboratory during the summer months and the fruits are then sprayed with various concentrations of oil, usually in combination with lead arsenate and some emulsifying agent. The

[1] Published as Scientific Paper No. 514 College of Agriculture and Agricultural Experiment Station, State College of Washington.

investigations herein reported were conducted at the Tree Fruit Branch Experiment Station at Wenatchee.

According to Spuler *et al.* (1931) light mineral oils (50 to 55 viscosity) were less efficient as ovicides than medium (70 to 75 viscosity) oils and these in turn were less efficient than heavy spray oils (110 to 120 viscosity). At a concentration of 0.5 per cent, 25 per cent of the codling moth eggs hatched where the light oil was applied, 21 per cent where the medium oil was used, and only 10 per cent in case of the heavy oil. At a concentration of 0.75 per cent, 22 per cent of the eggs hatched in case of the light oil, 15 per cent with the light medium and 6 per cent with the heavy oil. At concentrations of 1 and 1.5 per cent still greater efficiency of the oils as codling moth ovicides was observed. These studies were made in the insectary at Wenatchee between 1928 and 1930.

One-half per cent oil represented approximately a minimum concentration for an effective codling moth ovicide according to laboratory studies by Cecil E. Miller, Crop Protection Institute fellow at Wenatchee in 1932. One-fourth per cent was quite inefficient. On the other hand, increasing the concentration from 0.5 to 0.75 per cent resulted in only a slight increase in ovicidal value (Webster & Marshall 1934). The oil used in these studies was one furnished for experimental use by the Standard Oil Company of California and had a viscosity of 70 seconds Saybolt with an unsulfonatable residue of 90 per cent.

On the basis of data of this general nature, recommendations for the use of a medium summer oil (65 to 75 viscosity) at the rate of 1 gallon of oil emulsion to 100 gallons of water were made by Washington investigators in formulating spray recommendations for the state for 1931. The recommendations, in consequence, called for more oil than was actually needed as an ovicide for codling moth eggs. Since the Pacific mite also was affected by the cover sprays including oil, it was thought best to allow for some margin of safety. In fact, recent observations indicate that a higher concentration of oil may be necessary to kill the eggs of the Pacific mite than is needed for codling moth.

Marshall *et al.* (1935) showed that kerosene had very little ovicidal value even at a concentration of 2 per cent when used with lead arsenate and emulsified with casein ammonia. The maximum control at this concentration was 9.9 per cent according to studies in the insectary. On the other hand, the use of a 70-viscosity oil (90 per cent unsolfonatable) at a concentration of 0.5 per cent resulted in a mortality of 94 per cent.

Kerosene (viscosity about 34) seems to be out of the boiling point range of those fractions with high ovicidal value since at a concentration of 0.5 per cent there was a mortality of only 3.9 per cent. On the other hand the use of a medium, low unsulfonatable residue oil at the same time afforded a mortality of 79 per cent at the same concentration.[1]

Working under Marshall's direction in 1938, Stanley Strew obtained data on the ovicidal value of mineral seal oil, a highly refined product with a viscosity of approximately 42. The oil was used with lead arsenate, 3 pounds to 100 gallons of water, and emulsified with monoethanolamine and oleic acid. At 0.5 per cent this oil afforded 89 per cent control. Lowering the concentration to 0.25 per cent reduced the efficiency to only 54 per cent. None the less, it was apparent that a petroleum oil as light as mineral seal oil showed a rather high degree of efficiency as a codling moth ovicide when used at a concentration of 0.5 per cent. This figure is higher than it has usually been assumed to possess.

Further experiments at Wenatchee in 1939 under the direction of Joseph B. Moore afforded additional information on the ovicidal value of light spray oils. Using light, light-medium, and medium oils at concentrations of 0.5 per cent, C. C. Fox obtained a mortality of 74 per cent with a light oil, 84 per cent with a light-medium, and 86 per cent with a medium oil. The oils were emulsified with oleic acid and ammonia and were used without lead arsenate. The light oil had an unsulfonatable residue of 79, the medium 71, and the heavy oil only 66.

At the same time, another series of experiments were conducted where a highly refined oil (U.R. 90) was utilized. When used at a concentration of 0.5 per cent,

[1] Viscosity 76 seconds, U.R. 57 (A.O.A.C. method). Analysis by Kermit Groves, Assistant Chemist, Washington Agricultural Experiment Station.

egg mortality of 77 per cent was obtained with the light oil, 86 per cent with a medium oil and 90 per cent with a heavy oil. All were naphthenic base oils furnished us for experimental use by the Shell Oil Company. In general, the trend of investigations during 1939 indicated that oils classified as medium were superior to the light and light-medium oils in ovicidal value at a concentration of 0.5 per cent.

The problem was attacked with renewed energy in 1940 and by the end of the season it became evident that high ovicidal values were characteristic of light oils as well as medium oils and that results from the use of a light oil at a concentration of 0.5 per cent may fall only a little short of those obtained from a medium spray oil. With a light oil at this concentration, 96 per cent mortality was secured in 1940. With a light-medium oil, the mortality was 85 per cent,[2] while the use of a medium oil at this concentration afforded a mortality of 97 per cent. These oils were all highly refined.

Contrasted with these figures is another series of tests with a light oil having an unsulfonatable residue of 80. This was a commercial oil emulsion used to a considerable extent in the Yakima Valley. In this case, a concentration of 0.5 per cent resulted in a mortality of only 39 per cent, while a concentration of 0.75 per cent resulted in a mortality of 61 per cent. Efficiency in this event was much less than that obtained in 1939 with a light oil said to be from the same source. In general the ovicidal value of most of these low unsulfonatable residue oils has been quite variable.

Meanwhile the technique of obtaining eggs for use in the laboratory was improved so that more dependable results could be obtained. Natural mortality, which had been high in 1939 and also during the fore part of the 1940 season, was reduced to a minimum by August of that year.

Consistent results in ovicidal value were obtained in the laboratory in 1941 with a commercial miscible oil at 0.5 per cent. This oil is highly refined and the commercial product contains at least 98 per cent actual oil. In this series of tests a light oil resulted in 97 per cent, a light-medium oil in 96 per cent and a medium oil in 99 per cent mortality. While the light-medium oil appears to have been less efficient in these tests, we are inclined to believe that the difference may be due to experimental error. Even though the efficiency for both the light and light-medium oil may be less than that of a medium one, still the use of the lighter fractions does afford a high degree of efficiency.

Reducing the concentration to 0.33 per cent of this commercial miscible oil, resulted in 96 per cent control with the medium oil, but this was reduced to 88 per cent with the light-medium and to 83 per cent with the light oil. It is evident that 0.33 per cent is not sufficient to afford what we would like to consider adequate ovicidal value in a spray oil.

At concentrations ranging from 0.33 to 1.0 per cent this same commercial miscible oil gave high ovicidal values except at the lowest concentration. At 0.33 per cent the egg mortality was 83 per cent, at 0.5 it was 97 per cent, at 0.66 99 per cent, and concentrations of 0.83 and 1 per cent resulted in mortalities of 99 and 100 per cent respectively. It is evident that increasing the concentration from 0.5 to 0.66 or 0.83 per cent, or even to 1.0 per cent resulted in very little increase in efficiency.

These data may be compared with those obtained by using a commercial paste emulsion which represented a light oil with a high degree of refinement. Such an emulsion ordinarily would contain about 83 per cent actual oil. In computing the concentration in this series of tests, the per cent was based on the actual oil content. When used at a concentration of 0.25 per cent the mortality rate was only 46 per cent. On the other hand, the use of a 0.5 per cent concentrate increased the egg mortality to 92 per cent, which was further increased to 99 per cent when the concentration was raised to 0.75 per cent.

SUMMARY.—Evidence is presented which indicates that light petroleum oils (viscosity 50–55) with a high unsulfonatable residue and at a concentration of 0.5 per cent have a high ovicidal value (92 per cent mortality or better) for the codling moth.—2-16-42.

[2] This figure is low because of one day's results which bring down the average. Eliminating the figures for the one test the average mortality is 95.5 per cent.

LITERATURE CITED

Marshall, J., P. M. Eide and A. E. Priest. 1935. Increasing and maintaining lead arsenate deposits for codling moth control. Proc. Wash. State Hort. Assoc. (1934) **30**: 52–64.

Overley, F. L., E. H. Overholser and J. L. St. John. 1937. Spray residue removal studies of 1936. Proc. Wash. State Hort. Assoc. (1936) **32**: 127–31.

Spuler, Anthony, F. L. Overley and E. L. Green. 1931. Oil sprays for summer use. Wash. Agr. Expt. Sta. Bul. **252**: 1–39.

Webster, R. L., and James Marshall. 1934. Arsenic deposit and codling moth control. Wash. Agr. Expt. Sta. Bul. **293**: 1–31.

The Effect of Some Organic Halides on the Housefly

LYLE D. GOODHUE, W. N. SULLIVAN, and J. H. FALES, *U. S. Department of Agriculture, Bureau of Entomology and Plant Quarantine*

The use of certain insecticides in aerosol form as fumigants was suggested in previous communications (Sullivan *et al.*, 1940, 1941). Solutions of insecticides of low volatility were dispersed in air by spraying them against a hot surface, and the resulting aerosols were used in the same manner as vapors or gases. Aerosols composed of rotenone, pyrethrum, napththalene, and orthodichlorobenzene gave promising results, and as a continuation of the investigation many other organic compounds have been tested on a laboratory scale. Because methyl bromide is a good insecticide, the first series to be investigated comprised the organic halides, and data on 39 of them are reported in this paper.

MATERIALS AND METHODS.—The method of preparing and testing the aerosols was essentially the same as that described by Sullivan *et al.* (1940) except for changes required when the method was reduced to a laboratory scale. A 7-cubic-foot glass case was adopted as the fumigation chamber. The insecticidal solutions were dispersed by spraying them against an electric hot-plate held at 375° C. To avoid an undue rise in temperature in this small space, the hot-plate was mounted outside on a hinge in such a way that it could be swung over an opening in the wall of the chamber for spraying and removed immediately afterwards. One pane of glass on that side was replaced by a sheet of metal with a hole slightly smaller than the hot plate. A slide was provided to close the hole after the insecticide is sprayed. The mechanism is illustrated in figure 1.

The spraying apparatus, mounted inside the chamber, was adapted from a small nasal atomizer. It was attached to a 10-cc. graduated cylinder, which served as a reservoir, and a 7-mm. glass tube attached to the atomizer reached to within 5 mm. of the bottom. A telescoping tube having an inside diameter of 1 mm., fitting inside the larger tube, always rested directly on the bottom. This type of suction tube reduced the amount of liquid that could not be sprayed to about 0.05 cc. Air pressure from an 80-pound line, reduced to about 4 pounds by a bunsen valve, was used for the spraying.

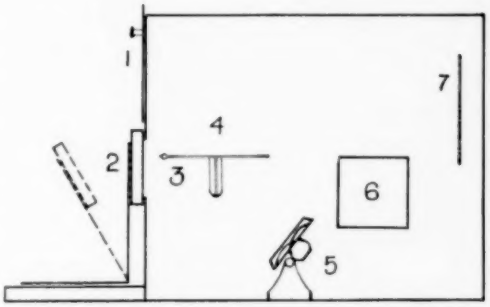

FIG. 1.—Diagram of laboratory-size fumigation chamber for testing insecticidal aerosols: 1, Slide; 2, hot plate; 3, hole in metal side; 4, atomizer; 5, ventilating fan; 6, insect cage; 7, thermometer.

The chamber and accessories were placed in a fume hood equipped with a ventilating fan. Another small fan inside the chamber was directed at the hole in the metal side both to assist in the ventilation between tests and to stir the aerosol for a short time during the test.

The chemicals were in general of the best quality obtainable commercially. Some were from stocks prepared in this laboratory, and a small number were industrial chemicals.

Houseflies from 3 to 5 days old were used as test insects. They were handled in 10-inch cubical cages with screen wire

on the top and two opposite sides. A cage containing from 200 to 300 flies was placed in the fumigation chamber. After an exposure of 30 minutes, the cage was removed and the flies were fed. Mortality counts were made in the usual manner after 24 and 48 hours.

During the test the estimated knockdown of insects after 10 minutes, the observed density of the aerosol, and the degree of agitation of the flies were recorded. At the end of 30 minutes the knockdown of flies and the amount of visible deposit of insecticide were noted. The temperature of the fumigation chamber was 32° ± 1° C.

The first test with each chemical was made at the rate of approximately 0.33 pound per 1000 feet (1 gram or 1 cc. to 198 liters). If the mortality was more than 60 per cent, the concentration was cut in half and a second test made. This procedure was repeated until the mortality dropped below 60 per cent. The test at the last concentration was always repeated as a check. The preceding tests were regarded as checks on each other. At least 2 cc. of an acetone solution of each chemical, containing 50 mg. of oleic acid, was always sprayed even when very small amounts of the insecticide were used. With some slightly soluble compounds more than 2 cc. was required. The oleic acid was added because it was found to be an effective activator of insecticidal aerosols. A report of an investigation of surface active agents in this connection has recently been published (Sullivan *et al.* 1941).

A standard of 2 cc. of orthodichlorobenzene plus 50 mg. of oleic acid was run each day to obtain data on the condition of the flies.

RESULTS.—The data on the various compounds are presented in table 1. Since only one run was made at some of the

Table 1.—Toxicity to the housefly of some organic halides.

	Concentration Lbs. per 1000 Cu. Ft.	Agitation[1]	Density of Smoke[1]	Visible Deposit[1]	Knockdown in 10 Minutes	Mortality in 24 Hours	Mortality in 48 Hours
3-Chloroacenaphthene	0.33	H	H	M	25%	100	100
	.16	M	H	L	25	96	99
	.08	M	H	L	5	70	85
	.04	L	H	0	0	61	89
	.02	L	M	0	0	63	75
	.01	L	L	0	0	5	16
2-Chlorofluorene	.33	H	H	L	90	100	100
	.16	H	H	L	5	100	100
	.08	H	H	0	0	100	100
	.04	H	H	0	10	88	96
	.02	M	M	0	0	75	95
	.01	L	L	0	0	18	38
9-Bromophenanthrene	.33	L	H	H	0	99	99
	.16	0	H	L	0	99	99
	.08	0	H	L	0	83	86
	.04	0	M	0	0	96	99
	.02	0	L	0	0	42	60
	.01	0	L	0	0	30	45
alpha-Chloronaphthalene	.33	M	H	0	90	95	99
	.16	M	H	0	85	13	15
alpha-Bromonaphthalene	.33	L	H	0	90	64	86
	.16	M	H	0	90	52	77
	.08	M	H	0	30	0	1
alpha-Iodonaphthalene	.33	M	H	0	95	89	91
	.16	M	H	0	90	52	69
	.08	L	H	0	80	4	6
Chlorinated biphenyl	.33	M	H	L	20	100	100
	.16	M	H	0	5	99	99
	.08	L	H	0	0	82	85
	.04	L	M	0	0	60	62
	.02	L	M	0	0	17	18
1,2,4-Trichlorobenzene	.33	M	L	0	95	94	98
	.16	M	L	0	40	4	4
Orthodichlorobenzene	.33	M	L	0	95	10	11
Chlorobenzene	.33	M	L	0	30	1	1

Table 1.—Toxicity to the housefly of some organic halides—*Cont.*

	Concentration, Lbs. per 1000 Cu. Ft.	Agitation[1]	Density of Smoke[1]	Visible Deposit[1]	Knock-down in 10 Minutes	Mortality in 24 Hours	Mortality in 48 Hours
Bromobenzene	.33	M	L	0	95	2	3
Iodobenzene	.33	L	L	0	80	2	3
Fluorobenzene	.33	M	L	0	0	0	1
Benzal chloride	.33	H	L	0	80	10	15
Benzotrifluoride	.33	L	L	0	0	0	0
Styrene dibromide	.33	M	L	0	60	99	99
	.16	M	M	0	5	18	49
Cyclohexyl bromide	.33	L	L	0	0	1	1
Chlorinated paraffin	.33	L	H	0	0	1	1
1,2,3-Tribromobutane	.33	M	H	0	99	66	69
	.16	M	M	0	35	0	1
tert-Butyl iodide	.33	M	M	0	0	0	0
n-Butyl chloride	.33	L	L	0	2	0	1
Trimethylene bromide	.33	M	L	0	65	35	42
Allyl bromide	.33	L	L	0	0	9	10
Ethylene chloride	.33	L	L	0	0	0	0
Tetrachloroethane (tech.)	.33	H	L	0	99	2	3
Pentachloroethane	.33	M	H	0	90	19	20
Hexachloroethane	.33	H	M	L	70	16	17
alpha, beta-dichloroethylene	.33	L	L	0	45	71	78
Trichloroethylene	.33	L	L	0	50	6	38
alpha beta-Dibromoethylene	.16	M	L	0	5	6	6
Ethylene bromide	.33	L	L	0	55	94	100
	.16	L	L	0	5	67	98
	.08	L	L	0	0	3	55
1,1,2-Tribromoethane	.33	H	M	0	100	1	1
sym-Tetrabromoethane	.33	L	H	0	95	61	81
	.16	M	M	0	85	3	5
Chloroform	.33	0	L	0	5	1	2
Bromoform	.33	H	L	0	100	1	1
Iodoform	.33	L	M	L	30	90	100
	.16	M	L	L	0	92	99
	.08	M	L	L	0	13	14
Methyl bromide	.33	L	L	0	0	1	3
Methyl iodide	.33	L	L	0	0	14	18
Methylene iodide	.33	H	L	0	100	7	27

[1] H = heavy, M = medium, L = light and 0 = none.

higher concentrations, no statistical treatment was made. The mortality figure at the lowest concentration for each compound is an average of two tests. The results given for the other concentrations were obtained from only one test, since each succeeding test is a fair check on the preceding one. Taken as a whole the data on each compound give a good indication of the most effective compounds. The results from 53 tests on the standard were grouped, and the standard deviation was calculated to be ± 4.5 per cent for the 24-hour counts and ± 5.5 per cent for the 48-hour counts. The mean kills were 13 and 17 per cent, respectively.

The compounds are arranged in the table in decreasing order of complexity of structure. Related compounds are grouped as closely as possible. The relative agitation of the flies, smoke, and visible deposit are included, because these factors might affect the practical use of the insecticide.

DISCUSSION OF RESULTS.—So far as the compounds were available, tests were made on several related compounds in a series. These tests show some trends regarding the correlation of toxicity with chemical structure, but the less toxic compounds were not run at enough concentrations for small differences to be distinguished. It was not considered worth while at this time to investigate these compounds further for use as insecticidal aerosols, especially since several highly toxic ones were discovered.

Some of the compounds tested, such as methyl bromide and chloroform, are too volatile to produce aerosols and are there-

fore not suited for this method of application. Some, such as allyl bromide and benzal chloride, are lachrymators, while others, for example, iodoform, leave undesirable odors or visible deposits. To be practical a compound must be toxic enough to give good results at such a low concentration that any undesirable properties are not apparent.

3-Chloroacenaphthene, 2-chlorofluorene, and 9-bromophenanthrene appear to be promising, since they gave a high mortality at 0.02 pound per 1000 cubic feet. The halogenated naphthalenes, already known to be good insecticides, were toxic as aerosols and a chlorinated diphenyl gave a high mortality. The physiological reaction of man and animals to many of these compounds is not known, and until such information is available they should be handled with discretion.

Since the exposure period in these tests was short, some good insecticides may have been overlooked. On the other hand, those compounds giving good results here should be more effective when used over a longer period.

SUMMARY.—A small chamber for testing aerosols on a laboratory scale has been developed and the toxicities of 39 organic halides to the housefly have been determined. Some of the more complex compounds, such as 3-chloroacenaphthene, 2-chlorofluorene, and 9-bromophenanthrene, were found to be effective at 0.01 or 0.02 pound per 1000 cubic feet. Some of the more volatile compounds, such as methyl bromide, which do not form aerosols, are not effective applied by this method.—2-11-42.

LITERATURE CITED

Sullivan, W. N., L. D. Goodhue and J. H. Fales. 1940. Insecticide dispersion. A new method of dispersing pyrethrum and rotenone in air. Soap **16**(6): 121, 123, 125.

Sullivan, W. N., E. R. McGovran and L. D. Goodhue. 1941. Fumigating action of a mixture of orthodichlorobenzene and naphthalene applied by a new method. JOUR. ECON. ENT. **34**(1): 79–80.

Sullivan, W. N., L. D. Goodhue and J. H. Fales. 1941. The use of fatty acids in insecticidal aerosols Science **94**: 444–5.

The Use of the Square Root Transformation and Analysis of Variance with Contagious Distributions[1]

WM. M. UPHOLT, *South Carolina Experiment Station, Clemson*

The statistical tests in most common use in agricultural entomology are designed to aid the experimenter in detecting differences in the mean infestation between two or more plots, when these differences are not apparent without the use of statistical tests. To function effectively in this manner, the test must possess two properties. It must indicate a difference between means when no such difference in fact exists, with a definite frequency not to exceed a level chosen by the experimenter and known as the level of significance. If use of the test results in an error of this type more frequently than expected, then the test is biased and its use results in a false sense of security.

In addition, to be of practical value, an unbiased test must enable the experimenter to detect a difference between means, when in fact an important difference does occur, with a reasonably large frequency, known as the power of the test. If the test fails in this regard, or has a low power, its value to the practical experimenter is questionable.

Every statistical test is based upon certain hypotheses in regard to the population being sampled. For example a very common hypothesis is that the samples from a given plot were selected purely at random. Usually one or more such hypotheses deal with the independence or frequency distribution of the variates. It is obvious that occasionally these hypotheses may not be strictly accurate descriptions of what actually occurs in practice. Nevertheless if the discrepancy is not too great, they may be quite satisfactory bases for statistical tests. If, on the other hand, the facts are

[1] Technical Contribution No. 92 from the South Carolina Experiment Station, Clemson, S. C.

known to diverge quite widely from the hypotheses, it may be well to investigate the effect upon the two properties of statistical tests above mentioned before reliance is placed upon the results.

STATEMENT OF PROBLEM.—One of the statistical techniques most commonly applied to results of entomological experiments is the analysis of variance and related F-test and t-test (Snedecor 1940). One of the hypotheses upon which this technique is based is the validity of a generalized error term, which involves the hypotheses that the samples are independent and normally distributed. It is now widely recognized that this hypothesis is not strictly accurate in the case of most insect experiments for, among other things, the samples by nature have a discontinuous distribution and the variance is frequently dependent upon the mean. Various suggestions have been made by Bliss (1937) and others of methods whereby this discrepancy might be circumvented and a valid estimate of a generalized error term be realized. In particular, for the case in which the data are small integers whose experimental errors follow the Poisson law, Bartlett (1936) has suggested the use of the square root transformation. More recently Cochran (1940) has discussed the theoretical basis of this transformation and has provided a certain amount of evidence that it is satisfactory for the case mentioned which is doubtless often encountered in entomological investigations.

However it is well known among field entomologists that in frequent cases insects are not distributed independently and therefore would not be expected to follow the Poisson frequency law. It is only necessary to mention social insects such as ants, gregarious insects such as the Japanese beetle, and insects which deposit eggs in masses rather than singly such as the European corn borer, to persuade a field entomologist that insects are not all distributed at random. The mechanism whereby such insects are distributed is not clear in all cases (Bliss 1941; Upholt & Craig 1940). Neyman (1939) has developed a mathematical theory to describe the mode of distribution of certain insects, such as the European corn borer, and has called this type of distribution mechanism a contagious distribution. His theory possesses the remarkable characteristic that his formulae are based upon certain assumptions regarding the actual biological behavior of the species, the relationship of these assumptions being then related to observable variables, namely the mean and the variance. The three biological factors which are assumed to determine the mean and the variance, and hence the exact shape of the distribution are: 1. The mean number of egg masses deposited in a unit of the plot. 2. The mean number of larvae surviving from each egg mass at the time the counts are made. 3. The greatest distance travelled by any of the larvae at the time the counts are made. Obviously the mean infestation is the product of the first two factors. The variance involves all three factors in a rather simple formula.

Aside from the theoretical interest attached to such a mathematical theory based upon biological assumptions, his formulae of Type A have been shown by Beall (1940) to fit satisfactorily the distributions actually observed in the case of the European corn borer. If this type of distribution obtains under Beall's conditions it is reasonable to assume that it may apply rather generally to European corn borer and possibly to other insects of similar habits. If this be true it furnishes an alternative hypothesis to that of data following a Poisson distribution, which may serve as a basis to test the use of the square root transformation in the analysis of variance and related tests.

The development of a mathematical justification for the use of such a transformation in this case is a job for a mathematician. But Neyman suggested that the author might set up a hypothetical experiment, based upon this set of hypotheses, and thus obtain empirical evidence of the results that might be expected.

PROCEDURE.—First it was assumed that there are five corn fields, each field containing thirty thousand hills of corn and each field being perfectly homogeneous at the time that the European corn borer deposited its eggs. The first of these fields is assumed to have approximately the same mean number of egg masses per hill as in the case reported by Beal (1940). Further it is assumed that at the time egg counts are made there are the same number of mean survivors per egg mass as reported by Beall. Thus the mean num-

ber of larvae per plant in this field is assumed to be four, approximately that found by Beall.

In order to make this hypothetical experiment approach more nearly what might actually occur in practice, the five fields are assumed to have different degrees of infestation. Thus the second field is assumed to have just half as many egg masses as the first, the third field three-fourths as many egg masses as the first, and the fourth field, five-fourths as many as the first. In so far as the mean number of survivors per egg mass is assumed to be constant over all four fields, this results in means of four, two, three, and five respectively, which seems to be a reasonable degree of variation, certainly not greater than is frequently found in nature. The fifth field is assumed to have the same number of egg masses as the first but, due to parasites, predators, or some other uncontrolled factor, only half as many larvae survive per egg mass as in the first field, thus the mean is reduced to two as in the second field and the variance is reduced appreciably.

Next, each field is divided into three equal plots each containing ten thousand hills of corn. Treatments are applied to these plots so as to make a randomized block arrangement of three treatments in five blocks, each treatment occurring once in each block or field. The three treatments include an untreated check designated as treatment *C* and two hypothetical test insecticides, designated as treatment *A* and treatment *B*. Treatment *A* is assumed to be a material that has no toxic effect and so kills no larvae thus leaving the mean infestation the same as in the check plot; but it is assumed to have a repellent effect, as a result of which the larvae dislike the corn and continue travelling instead of entering the stalks, and thus travel twice as far from the egg mass before they enter the stalks. Thus the mean infestation is not affected but the variance is reduced appreciably. Treatment *B* has quite the opposite effect. Again it has no toxic effect but it is appreciably anesthetic or paralytic so that the larvae are lethargic, and whereas they all recover, they have travelled only half as far at the time counts are made as have those in the check plots.

Thus we have an hypothetical, randomized block experiment the results of which are known at the outset. The number of larvae on each of the 10,000 hills in each plot can be determined by applying Neyman's formulae for a contagious distribution of Type *A*. The resulting frequency distribution of the hills in plot *C* of block *I* will be practically the same as that actually observed and reported by Beall. The frequency histogram for this plot is presented in figure 1. In the same figure is presented for comparison the Poisson frequency histogram that would be expected if the larvae were distributed entirely independently and at random.

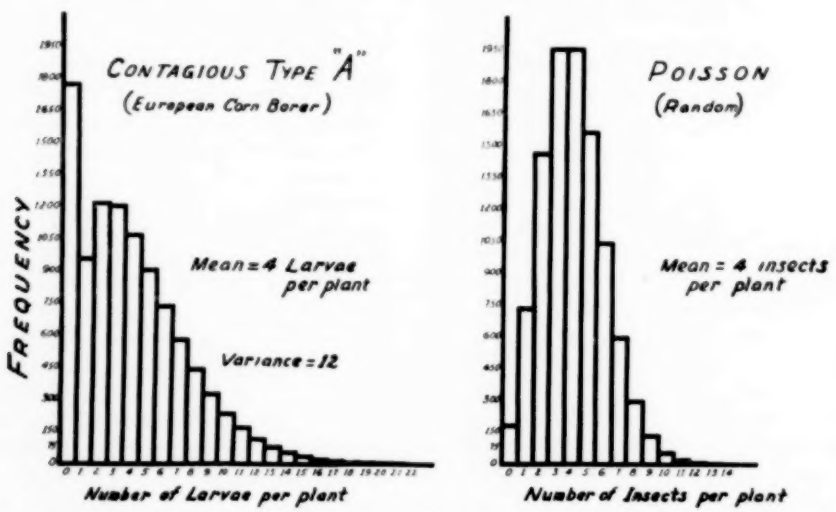

FIG. 1.—Frequency histograms for contagious Type *A* and Poisson distributions both having means equal to four.

Similar frequency histograms were constructed for each of the fifteen plots. These are presented in figure 2 so that the effect of the hypothetical insecticides and of the differences between blocks can be seen by comparison. The blocks are arranged in order of increasing infestation, starting at the top with the block that had the basic mean number of egg masses per plant but only half the basic mean number of survivors per egg mass. The second row represents the block which had half the basic mean number of egg masses, third row represents the block with three-fourths of the basic mean number of egg masses, the fourth row represents the block with the basic mean number of egg masses as reported by Beall, and the bottom row the block with the greatest mean number of egg masses per plant, being five-fourths as large as the basic number. The column to the left represents treatment *A* which has increased the distance travelled and thus decreased the variance as compared with the untreated check, *C*, as represented in the center column. The third column represents treatment *B* which reduced the distance travelled, by half, thus increasing the variance.

As will be seen by the histograms of figure 2, there were a large number of hills in most plots which had no insects in them. Therefore, to attempt to select the smallest size sample that an entomologist would be apt to use, it was decided to select two hills from each plot entirely at random and combine the number of insects in these two hills, using their sum as the sample datum. These random samples were selected by the use of Tippett's (1927) table of random sampling numbers. This provided a set of data such as might reasonably be encountered by an entomologist working with an experimental design of this sort.

This set of sample data was transformed by using the system recommended by Snedecor (1940) in such a case. Because the range of samples was largely confined between zero and ten, though numbers in the twenties were occasionally encountered, one-half was added to each number and then the square root was extracted. This set of transformed data was then analyzed by atypical analysis of variance, calculating the mean squares associated with blocks, with treatments, and with errors. From these, *F*-values were calculated for treatments.

Using the differences between treatment sums as the numerator and the square root of ten times the error mean square as the denominator, *t*-values were calculated for treatment *C* minus treatment *A* and treatment *C* minus treatment

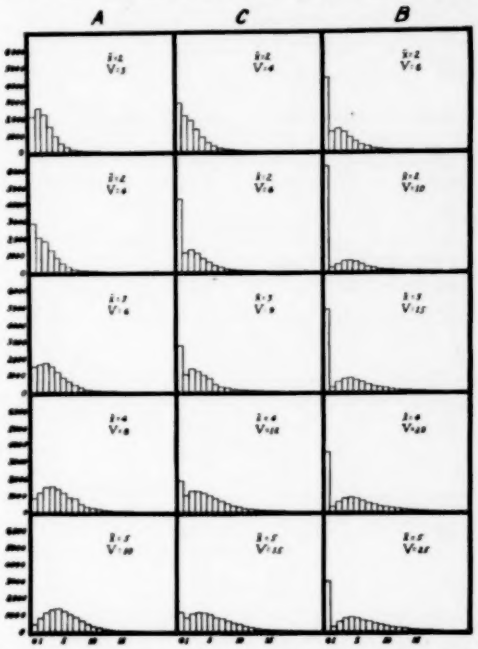

FIG. 2.—Frequency histograms for the 15 plots in the hypothetical experiment. Letters above the columns represent corresponding treatments.
$\bar{x}$ = mean number of larvae per plant.
V = variance of errors.

B. The *t*-value for treatment *A* minus treatment *B* might be difficult to interpret in an actual field experiment. However, since this experiment is purely hypothetical, meanings may be assigned to the various treatments at will, so the *t*-value for treatment *A* minus treatment *B* was also calculated in so far as it furnished a comparison between plots with greater extremes of variance and therefore would be more apt to detect any bias that might exist in the technique.

One hundred sets of random samples were selected in this manner and the *F*-values and *t*-values thus obtained were tabulated.

DISCUSSION.—When two sets of variables are transformed by extracting the square root of each unit, the relationship of the means is affected as well as the

Table 1.—Treatment means and standard errors resulting from combining the five blocks in each treatment using original units.

Units		Treatments				S.E.	Coefficient of Variation
		A	*B*	*C*	Mean		
X	mean	3.197	3.198	3.192	3.196	0.0026	0.00081
	S.E.	2.738	4.065	3.228			
$\sqrt{X}$	mean	1.5556	1.2703	1.4527	1.4262	0.1180	0.08271
	S.E.	0.8812	1.2589	1.0402			
$\sqrt{X+0.5}$	mean	1.7867	1.6467	1.7339	1.7224	0.0577	0.03350
	S.E.	0.710	0.993	0.824			

relationship of the standard errors if the variance of the two sets are widely different. This is illustrated in the present case by combining all five plots to which each of the three treatments was applied. When this is done, dropping one digit from each figure so that it is on the basis of 5,000 samples from each treatment, the means of the three treatments are all practically the same, as can be seen from table 1. The coefficient of variation, that is, the ratio of the standard error to the mean, is only eight ten-thousandths. The standard errors are, of course, widely different in the three cases.

The square root transformation is designed to reduce the standard error of different plots to a common figure. As can be seen from the second row of table 1, when each variable is transformed by extracting its square root, the variation in standard errors is reduced, but also there is a rather large variation in means introduced. In the populations resulting from this transformation, treatment *A* would appear to produce an appreciable increase in infestation over the control and treatment *B* would appear to produce a decrease in infestation over *C*. In fact the coefficient of variation of the means is increased to more than eight hundredths or more than one hundred fold increase in variation between means as a result of this transformation.

The addition of one-half to each variable before extracting the square root introduces a compensating bias, as shown in the third row of table 1, which reduces the variation between means somewhat. However, the coefficient of variation, over three hundredths, is still increased more than forty-fold over the variation in the untransformed variables.

In the hypothetical experiment under consideration the sample data were actually the sum of two variables selected at random. This increase in size of sample would be expected further to reduce the bias introduced by the transformation, for such a transformation affects small numbers much more than it does larger numbers. To find the exact effect of this transformation on the larger samples would require the calculation of the expected distribution of the sum of two samples.[1] However an approximation of the effects can be obtained from the five hundred random samples previously selected from each treatment. These results are presented in table 2. As can be seen from the first row of this table, the means as estimated from five hundred samples show considerably more variation than do the actual population parameters. However, the coefficient of variation, less than six one-thousandths, is still much less than that for the transformed parameters as presented in table 1. Again it can be seen from the second row of table 2 that the transformation has introduced a considerable bias even in the case of these larger samples. This time the increase in coefficient of variation is somewhat over three fold.

The fact that this transformation decidedly increases the mean of the population as the variability is decreased within the limits of this experiment would naturally introduce a bias into the analysis of variance and related tests. This follows because even in the case where there is in fact no difference between the means of the original populations, there will be a difference between the means of the transformed populations if there was an appre-

[1] This has been done by Miss E. Fix, of the University of California, and the results are in agreement with those reported herein.

Table 2.—Treatment means and standard errors resulting from combining two random samples from each of the five blocks in each treatment (total of 500 samples from each treatment).

UNITS		TREATMENTS			Mean	S.E.	COEFFICIENT OF VARIATION
		A	*B*	*C*			
S	mean	6.41	6.37	6.46	6.413	0.0370	0.0058
	S.E.	4.161	5.5512	4.977			
$\sqrt{S+0.5}$	mean	2.500	2.384	2.458	2.447	0.0480	0.0196
	S.E.	0.811	1.086	0.958			

ciable difference between the variance of the original populations as there is in the hypothetical case under consideration. Therefore if the test possesses any power at all to detect differences as small as those introduced by the transformation, then it will report a difference between means, when in fact no difference exists, with a frequency greater than that set by the chosen level of significance.

The frequency distribution of the one hundred values of F associated with treatments as obtained from the sample data in the present experiment was determined. The range of possible values was divided into twenty classes, such that the F values with these degrees of freedom would be expected to be equally distributed among the twenty classes if the test were unbiased and if there were no differences between means. The chi-square test did not detect a difference between the empirical distribution obtained from our samples and the theoretically expected distribution. Similar distributions were obtained for the values of t associated with differences between treatments C and A, treatments C and B, and treatments A and B. In no case did the chi-square test detect differences between the empirical distributions and those theoretically expected.

The fact that no bias was detected leads to the conclusion that under the conditions of this hypothetical experiment, with sufficiently large samples and the complete transformation, the analysis of variance and t-test can be used, without undue danger of an error of the type under consideration, with a greater frequency than expected at the level of significance chosen, except in extreme cases.

POWER OF THE TEST.—The transformation was shown to introduce an appreciable degree of variation between the means of the three treatments and yet the empirical distributions of F and the t's did not indicate a noticeable bias in these tests. Thus the tests must lack somewhat in sensitivity.

Referring again to the bottom rows of table 1 and 2, it is apparent that, even after the transformation, there is considerable variation between the standard errors of the various treatments. All of this variation, as well as the variation within each treatment due to its type of distribution, must enter into the estimate of the error mean square of the analysis of variance. Since this error mean square is the source of the generalized error term used in both the F-test and the t-test, its increase in size would be expected to decrease the power of the test. Such a decrease in power might well explain why no bias is apparent in the tests.

Even without looking for an explanation of the lack of apparent bias, but accepting the fact that the test appears to be "safe" for use in this case, it is very desirable to investigate the power of the test to detect differences in means when appreciable differences in fact do exist, for the purpose of any such statistical test, as explained in the introduction, is to detect such differences when it would be difficult to do so without the aid of the test.

An adequate investigation of the power of the test when applied to distributions of the type reported by Beall for European corn borer, would require setting up a new hypothetical experiment similar to the one here described, but with somewhat different treatments. However a certain amount of information may be gleaned by changing slightly the assumptions upon which the experiment was built without changing the distributions. Thus if the differences between A, B, and C, namely differences in distance travelled, are assumed to be the result of some factor other than treatment, such as season of year

locality in relation to climate, or different years, then *A*, *B*, and *C* may be assumed to be three different blocks. These three blocks may be divided into five plots each, and treatments applied which are, with one exception, toxic or repellent to the moths before oviposition takes place, thus reducing the mean number of egg masses without affecting the mean number of survivors or the distance travelled. In the one exception, treatment *V*, the treatment was applied after the eggs were deposited and resulted in the death of half of the

Table 3.—Results of tests when applied to plots of hypothetical experiment when actual differences do exist.

	F-Test	
RANGE OF ACTUAL MEANS	NO. OF CASES IN 100 SURPASSING 5 PER CENT LEVEL SIGNIFICANCE	NO. OF CASES IN 100 SURPASSING 1 PER CENT LEVEL OF SIGNIFICANCE
4 to 10	23	6
	t-test	
ACTUAL MEANS	*t* EXCEEDING 5 PER CENT LEVEL	*t* EXCEEDING 1 PER CENT LEVEL
8 to 10	0	0
6 to 8	9[1]	2
4 to 6	9[2]	1
6 to 10	8[1]	1
4 to 8	13	0
4 to 10	23	2
4 to 8[3]	8	0

[1] In one of these cases test exceeded 5% level in negative direction.
[2] In two of these cases test exceeded 5% level in negative direction.
[3] Difference in means result of reduction in mean number of survivors per egg mass.

larvae which would normally have survived. Moreover, in this case it must be assumed that the basic infestation was similar to the final infestation in treatment *I*.

Upon these assumptions we can use the same samples as previously to calculate the values of *F* and *t* when differences between means as great as four and 10 do in fact exist.

Of the one hundred values of *F* calculated for this case, only twenty-three values exceeded the 5 per cent level of significance and only six exceeded the one per cent level of significance.

The *t*-test is used to compare the sums, or means, of two treatments and in this case there are available seven such comparisons as listed in the first column of table 3. The first six reductions in means are a result of reductions in the mean number of egg masses deposited per plant. The last reduction in means is a result of reduction in the mean number of survivors per egg mass. As shown in the second column of table 3, only when the reduction in means was sixty per cent did the *t*-test detect this difference at the five per cent level of significance as often as twenty-three times out of the one hundred trials. In cases where the reduction in means was as great as forty per cent, the *t*-test made the serious error of indicating that the treatment with the lower mean actually had the greater mean at least once out of the one hundred trials. It is particularly noteworthy that the *t*-test did not detect actual differences in means at the one per cent level of significance more often than it would be expected to if no such differences actually existed—this, in spite of the rather large differences that did exist in certain cases.

Apparently, as indicated by the last row of table 3, the power of this test would be no greater if the differences in means were the result of insecticides which killed the larvae rather than reducing the number of egg masses.

CONCLUSIONS.—The evidence presented indicates that the square root transformation introduces a definite bias into means when applied to contagious distributions of the type that might reasonably be expected to be met with at least occasionally in entomological research. This bias may be reduced in certain cases at least, by adding one-half to each figure before extracting the square root and by increasing the size of samples.

Under reasonable conditions the net bias introduced by the transformation is not sufficiently great to invalidate the analysis of variance and the related *F*-test and *t*-test.

The large variance frequently present in contagious distributions, augmented by additional variability that may be introduced by treatments, is very apt to increase the generalized standard error so much that the test has little power to detect differences in means even when relatively large differences do in fact exist. Whether this low sensitivity of the test is sufficient to make it of no value is a question for the individual experimenter to decide for himself. The power of the test may be increased by using still larger samples, but even for very large samples it

would likely be relatively insensitive. Thus there may be some doubt as to whether it permits the experimenter to detect actual differences more readily than he would be able to do without the benefit of the test.

Nevertheless, until such a time as more powerful tests are available, if such do exist, this transformation and test may be a satisfactory guide for the experimenter if not too much reliance is put upon it.

SUMMARY.—The purpose of the statistical tests most frequently used by agricultural entomologists is to aid the experimenter to detect differences in means of plots when important differences do in fact exist. To do this the test must be unbiased in the sense that it does not indicate a difference, when no difference actually exists, with a frequency greater than the level of significance chosen. In addition it must be sufficiently sensitive to detect important differences with an appreciable frequency when such differences do exist.

The analysis of variance and related *F*-test and *t*-test are based on hypotheses not always met in entomological practice. The square root transformation has been suggested to make this statistical method more widely applicable to entomological data.

The above two properties of the analysis of variance and related tests are investigated in a hypothetical experiment for the case in which the data follow a contagious distribution and are transformed by adding one-half and extracting the square root, before applying the analysis.

The transformation is found to introduce a bias into the means but in reasonable cases this bias is not sufficient to invalidate the analysis.

The type of distribution and possible effects of treatments may result in such a great generalized error term that the analysis has very little power to detect rather large differences in means that may occur.

It is concluded that at least until more powerful tests are available for such cases, analysis of variance of the transformed data may be a satisfactory guide for the experimenter if not too much reliance is placed on the results.[1]—2-20-42.

[1] The author wishes to express his deep-felt appreciation to Professor J. Neyman of the University of California for suggesting the problem, describing the appropriate technique, and guiding it to completion, as well as for furnishing various necessary calculations. Thanks are due to my wife, Glynn Beckham Upholt, for assistance in many of the laborious calculations.

LITERATURE CITED

Bartlett, M. S. 1936. The square root transformation in the analysis of variance. Jour. Roy. Stat. Soc. Suppl. **3**: 68–78.

Beall, G. 1940. The fit and significance of contagious distribution when applied to observations on larval insects. Ecology **21**: 460–74.

Bliss, C. I. 1937. Analysis of field experimental data expressed in percentages. Plant Protection (Leningrad), pp. 67–77.

Bliss, C. I. 1941. Statistical problems in estimating populations of Japanese beetle larvae. JOUR. ECON. ENT. **34**: 221–32.

Cochran, W. G. 1940. The analysis of variance when experimental errors follow the Poisson or binomial laws. Ann. Math. Stat. **11**: 335–47.

Neyman, J. 1939. On a new class of "contagious" distributions, applicable in entomology and bacteriology. Ann. Math. Stat. **10**: 35–57.

Snedecor, G. W. 1934. Analysis of variance and covariance. Collegiate Press; Ames, Iowa.

Snedecor, G. W. 1940. Statistical methods applied to experiments in agriculture and biology. 3rd. ed. Iowa State College Press; Ames, Iowa.

Tippett, L. H. C. 1927. Random Sampling Numbers. Tracts for Computers, XV. Cambridge Univ. Press, London.

Upholt, Wm. M., and R. Craig. 1940. A note on the frequency distribution of black scale insects. JOUR. ECON. ENT. **33**: 113–14.

DR. E. M. LIVINGSTONE AT FT. LEWIS

Dr. E. M. Livingstone, of the Bureau of Entomology and Plant Quarantine, formerly stationed at New Orleans, La., has entered the army and is a member of the 56th Medical Battalion, stationed at Ft. Lewis, Washington. He may be addressed at Ft. Lewis, A.P.O. 309.

GEORGE A. ROOT DIES IN ARIZONA

We are informed that Mr. George A. Root, of Nogales, Arizona, a member of our Association, has recently died. An obituary notice will be published in an early issue of the Journal, if one can be secured.

A Method for Determining Insecticidal Effectiveness Using *Aphis rumicis* and Certain Organic Compounds[1]

WILLIAM MOORE[2] and C. I. BLISS[3]

For the past several years a series of chemicals has been examined in a search for compounds possessing insecticidal properties. These chemicals were tested as fumigants, stomach poisons and contact insecticides on different types of insects. The present paper deals only with tests of certain contact insecticides, which penetrate into the insect through its integument or its tracheal system.

EXPERIMENTAL METHODS.—*Aphis rumicis*, a black aphid found on nasturtiums, is frequently used in experimental work with contact insecticides. This species may be grown readily in large numbers upon potted nasturtiums. It infests the stems, petioles, and primarily the under side of the leaves where it is easily reached by sprays. The aphids were grown in a greenhouse with protection over the doors and ventilators to prevent the entrance of parasites or predatory insects.

Each test used a pot containing several young nasturtiums infested with all stages of the aphid. The plants were sprayed and the pot then placed on its side in a shallow, light-colored tray. The edges of the tray were greased so as to prevent the escape of the aphids. Two days later all insects both on the plant and on the tray were examined. All those able to move a leg or antenna were called living and the others were classed as dead. An untreated pot of infested plants was handled in a similar manner and the dead insects from these plants established the natural mortality.

In applying a contact poison it is essential that the spray wet the insect, and for this purpose a wetting agent is added to the spray. For the preliminary experiments a 65 per cent solution of acetone in water was found to wet the insect satisfactorily and to kill comparatively few aphids, with the added advantage that it dissolves a large range of chemical compounds. In each test a pot of infested plants was sprayed with 65 per cent acetone solution to determine the kill due to the wetting agent alone.

In making preliminary tests all chemicals were applied at a concentration of 1 to 500 in 65 per cent acetone in distilled water. A chemical failing to give a high kill at this concentration was discarded. Compounds effective at 1:500 were then tested in dilutions of 1 to 500, 1 to 1000, 1 to 2000 and 1 to 4000 in 65 per cent acetone solutions.

After a study of more than 400 compounds an active chemical grouping was found in the substituted glycinonitriles. From tests on a series of these compounds those with a double substitution of the nitrogen proved to be the most effective and to cause the least plant injury. Five of these having nearly the same toxicity looked promising after the preliminary experiments.

The question then arose as to whether any one of the last five was significantly more toxic than the others under field conditions. They were to be tested in comparison with nicotine, a standard contact poison. One of these chemicals tended to crystallize at normal temperatures; hence a mixture of it with an oily ester was prepared. The ester itself had a fair toxicity to aphids and it was thought that a 50:50 mixture might have approximately the same toxicity as the pure material. This gave seven materials to be compared at different concentrations under different conditions of temperature and humidity.

A = A standard nicotine spray, *Black Leaf 40*.
B = Dibenzyl glycinonitrile.
C = Isoamyl phenyl glycinonitrile.
D = Diphenyl glycinonitrile.
E = Benzyl phenyl glycinonitrile.
F = Mixed amyl-phenyl glycinonitrile.
G = 50-50 Mixture diphenyl glycinonitrile and dioctyl fumarate.

In order to approach field conditions several procedures were adoped. The 65 per cent acetone wetting agent was replaced by dioctyl sodium sulfosuccinate at a concentration of 1 to 5000, which gave good contact with the insects without too high a kill when used alone. To

[1] Read before the Biometrics Section, American Statistical Association, at the meeting in New York, December, 1941.
[2] American Cyanamid Company, Stamford, Connecticut.
[3] Biometrician, Connecticut and Storrs Agricultural Experiment Stations.

obtain free circulation of air the plants were sprayed outdoors and the trays placed on a table under a tent without side walls. In this manner the insects were fully exposed to air movements but protected from rains.

For each chemical a spray mixture at a concentration of 1 to 800 was prepared with a 1 to 5000 solution of the wetting agent. After spraying the aphids on one pot of nasturtiums, the remaining mixture was further diluted with the same solution of the wetting agent to bring the concentration of the chemical to 1 to 1600. In a similar manner dilutions of 1 to 3200 and 1 to 6400 were prepared and applied for each chemical. Since *Black Leaf 40* consists of 40 per cent nicotine in the form of nicotine sulfate, sufficient sodium hydroxide was added to free the nicotine. The concentrations for *Black Leaf 40* are in terms of *Black Leaf 40*, not nicotine.

PLAN AND DATA OF THE FINAL TESTS.—The initial exploratory experiments tested a larger number of compounds on the basis of the percentage kill of aphids and chemicals not meeting the minimal requirements were discarded. In the final experiments, however, seven potential insecticides were to be related to each other quantitatively, by determining the relative concentrations of each which would kill the same percentage of aphids. With the facilities at hand only three of the seven chemicals could be tested on the same day. Because the aphid populations on the different pots varied continuously, both in development and in susceptibility, the relative toxicity of compounds tested on different days would be less reliably determined than that of compounds tested on the same day. To meet this difficulty the four concentrations of every chemical were repeated on three different days, each time with four concentrations of two other materials. Seven days were required to complete the experiment and in its course every chemical occurred once and only once on the same day with every other chemical.

An experiment meeting these conditions has been designated by Yates (1940) as one in "balanced incomplete blocks." Since the number of chemicals equaled the number of days on which the sprays were applied, the design was based upon a 7 by 7 latin square. The first three rows of the latin square below represents the treatment pattern followed in the present case.

	Chemicals tested on July						
	9	10	22	23	24	30	31
Present experiment with 3 replicates	A	C	D	G	B	E	F
	B	E	C	A	F	G	D
	D	A	G	F	C	B	E
	C	G	E	D	A	F	B
Plan suitable for experiment with 4 replicates	E	D	F	B	G	A	C
	G	F	B	C	E	D	A
	F	B	A	E	D	C	G

If four chemicals could have been tested on each day, the last four rows would represent an experiment in balanced incomplete blocks with four replicates of each chemical. A source of variation corresponding to the rows can also be balanced with a plan of this type, and when this is done the design is known as a Youden square (Youden 1940). In the present case, however, only the differences between columns or days were of interest. The environmental conditions on each day and the original data for the four dilutions of chemical are given in table 1 together with the counts of aphids for a spray of the wetting agent alone at 1 to 5,000 and an untreated check.

The mortality of the aphids on the plants sprayed with the 7 chemicals was a resultant of (1) natural mortality, (2) the toxicity of the wetting agent, dioctyl sodium sulfosuccinate, at 1 to 5,000, and (3) the toxicity of the insecticide. These three sources were assumed to act independently of each other. The natural mortality varied from 2.9 to 29.5 per cent on the seven days of the experiment, and the mortality ascribable to the wetting agent from 9.0 to 45.4 per cent. It is evident that even without insecticidal treatment the aphids varied considerably from day to day. If the causes of death were independent, the net percentage kill from each application of insecticide could be computed by the usual formula,

$$\text{Per Cent Kill} = \frac{P_t - P_w}{100 - P_w}, \qquad (1)$$

where P_t is the per cent dead on the plant treated with insecticide and P_w is the per cent dead on the plant sprayed on the same day with the wetting agent alone. These percentages formed the basic units for further analysis of the data.

CALCULATION OF THE CONCENTRATION KILLING 95 PER CENT.—For each of seven chemicals, the data in table 1 rep-

resent three dosage-mortality curves, each based upon the per cent kill at four different concentrations. Many experiments have shown that a diagram of percentage kill plotted against the concentration or dose is commonly an asymmetrical, sigmoid curve, but in most cases, especially at mortalities above 20 to 40 per cent, these same data can be plotted as straight lines on logarithmic-probability paper. Instead of using specially-ruled cross-section paper, concentrations may be transformed to logarithms and percentages to units called "probits" by tables that are readily available (Bliss 1935). The new units plot as straight lines on ordinary cross-section paper, and are essential in calculating the lines of best fit. The next step, therefore, was to transform concentrations to logarithms and percentages of less than 100 to empirical probits, and to plot each curve individually. Three such curves for July 31 are shown in figure 1.

Where 100 per cent kill is observed, the probits cannot be read from the same table. One pot of nasturtiums in each of five series had no surviving aphids, and in these cases a straight line was fitted by inspection to the remaining three points. From the expected probit, interpolated from the line at the log-dose killing 100 per cent, a corrected probit could be determined by means of table 12 given by Fisher & Yates (1938). In the test of chemical D on July 9 there were no survivors from either of the two higher concentrations and at both of the lower concentrations the kill exceeded 99 per cent. When the log-concentration killing 95 per cent of the aphids or the log-LD95 was computed from these data and compared with the log-LD95 for the other tests on chemical D and for the other two chemicals on July 9, the inconsistency was marked. The kill of aphids exceeded that expected from sprays 3 times as concentrated. Because of the discrepancy, this

Table 1.—Original counts of the mortality of Aphis rumicis sprayed with seven insecticides and the environmental conditions of the experiment.

Date—July	9	10	22	23	24	30	31
Temp.	74°F.	78°F.	84°F.	71°F.	79°F.	83°F.	78.5°F.
Rel. Hum. Per Cent	71	67	66	90	71	84	69
Dead	A 953	A 538	C 584	A 604	B 513	B 497	D 347
Total	955	541	609	610	514	499	349
	586	678	451	455	375	405	400
	593	679	514	455	385	411	413
	679	519	276	480	306	366	132
	710	637	428	491	390	411	193
	328	303	432	333	286	669	192
	398	684	772	461	420	748	304
	B 752	C 602	D 393	F 580	C 364	E 547	E 445
	753	621	393	612	389	549	446
	718	500	533	378	203	357	304
	721	566	538	493	260	357	310
	291	396	413	343	195	481	439
	308	578	433	561	341	500	473
	517	397	535	155	247	548	357
	548	779	600	285	499	603	460
	D 703	E 419	G 458	G 368	F 319	G 325	F 299
	703	421	458	369	346	325	319
	477	614	363	520	208	432	340
	477	631	365	522	244	434	447
	655	353	620	499	259	288	187
	657	483	650	523	342	296	332
	699	497	602	235	179	385	127
	702	706	897	326	325	427	355
Spreader	240	196	256	199	179	282	42
	497	632	870	579	404	523	449
Check	42	69	51	16	91	103	13
	579	668	687	561	477	349	434

series has been omitted from subsequent calculations.

Inspection of the diagrams for the individual series indicated no systematic departure from linearity. The plotted points either adhered closely to a straight line or followed a concave as often as a convex trend. Since it seemed a better approximation than any alternative, a provisional straight line was computed from the mortality in probits and the concentration in logarithms for the 20 valid series.

Beginning with an initial concentration of 1 to 800, the active chemical of the spray mixture was diluted successively by one-half between applications. This led to a series of concentrations spaced at equal logarithmic intervals of 0.3 or the logarithm of 2. To avoid negative values, the smallest concentration, 1 to 6,400 with a logarithm of −3.806, was designated as 1, with a logarithm of 0, the remaining log-concentrations being 0.3, 0.6 and 0.9 respectively. The calculations have been made in this modified scale and only in the final step reconverted to the original concentrations by subtracting 3.806 from the log-concentration of each chemical killing 95 per cent of the aphids (log-LD95). The computation of the dosage-mortality curve for each series was further facilitated by replacing the log-concentrations of 0.9, 0.6, 0.3 and 0 with the coefficients 3, 1, −1 and −3 respectively. On the assumption that the corresponding probits were of equal weight, a curve could be calculated for each series by the technique described by Bliss & Marks (1939) and illustrated in table 2 for the determinations with chemical D on July 31.

The curve for chemical D has been computed in table 2 without reference to the curves for series E and F, which were

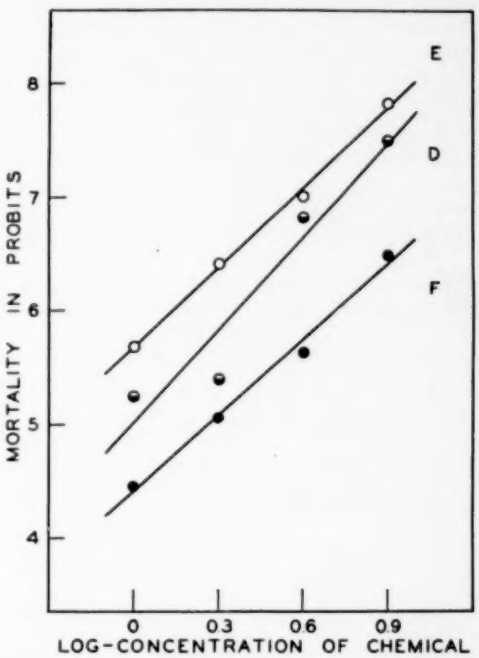

FIG. 1.—Dosage-mortality curves for sprays of chemicals D, E and F against *Aphis rumicis* in tests on July 31.

run on the same day. Independent curves have also been determined for the latter two series and all three are plotted in figure 1. If these three series could be fitted by lines which were parallel as well as straight, they would be equidistant at

Table 2.—Calculation of provisional dosage-mortality curve for Chemical D on 7/31.

Concentration	Log x	Total Aphids	Dead Per Cent	Killed Per Cent	Probit y	Coef. X	Xy
1 to 800	0.9	349	99.43	99.37	7.49	+3	22.47
1 to 1600	0.6	413	96.9	96.6	6.82	+1	6.82
1 to 3200	0.3	193	68.4	65.1	5.39	−1	−5.39
1 to 6400	0	304	63.2	59.4	5.24	−3	−15.72
Spreader		449	9.4				
Total	1.8				24.94	0	8.18

Slope of curve, $b=\frac{2\,S(Xy)}{0.3\,S(X^2)}=\frac{2\times 8.18}{0.3\times 20}=2.727$. Mean logconc., $\bar{x}=\frac{1.8}{4}=0.45$; mean probit, $\bar{y}=\frac{24.94}{4}=6.235$. Equation of provisional curve: $y=\bar{y}+b(x-\bar{x})=6.235+2.727(x-0.45)$. Total variation in $y=[y^2]=S(y^2)-\bar{y}S(y)=159.1222-(6.235)(24.94)=3.6213$, of which $\frac{S^2(Xy)}{S(X^2)}=\frac{8.18^2}{20}=3.3456$ is due to the slope of the dosage-mortality curve, leaving a residual $[y^2]=3.6213-3.3456=.2757$ with 2 degrees of freedom representing the error about the curve.

all levels of kill and the toxicities of any two of the three chemicals could be expressed as a difference in logarithms or as a simple ratio of concentrations. Two spray mixtures containing the chemicals in the proportions represented by this ratio would be expected to kill equal numbers of insects, whether applied at a high or at a low concentration. The seven chemicals could be compared more easily, therefore, if the three curves determined together were always parallel within the experimental error so that they could be represented adequately by their combined slope. The problem would be still further simplified if these combined slopes did not differ from day to day and a single combined slope held for all series within the limits of the experimental error.

Continuing our assumption of equal weight for each observation, both possibilities could be tested by an analysis of the variance between slopes in comparison with the residual variation about each individual curve. The single combined slope relating probit kill and log-concentration for the 20 valid series of the experiment has been determined by summing the products Xy over all series, totalling $S(Xy) = 154.97$, and dividing by twenty times the denominator for an individual curve, giving $b_c = (2 \times 154.97) / (20 \times 0.3 \times 20) = 2.5828$. The variation in the probit kill (y) within series that was accounted for by using this combined slope for all series was equal to $S^2(Xy) / S(X^2) = 154.97^2 / 400 = 60.0393$, and has been listed in the first row of table 3.

Instead of combining the Xy's for all 20 valid series into a single slope, they have also been combined by days to obtain seven daily slopes. The additional variation between these daily slopes has been computed from the sum of the seven $S^2(Xy)/S(X^2)$ for each day, subtracting the variation attributable to b_c to obtain .9095 for differences between the daily slopes in the second row of table 3. Finally an individual dosage-mortality curve has been determined for each series as illustrated by the example in table 2, and the 20 $S^2(Xy)/S(X^2)$ computed separately for each curve totalled 2.3243 over and above the effects of b_c and of the variation between the daily slopes.

Table 3.—Comparison of the slopes of the curves relating probit kill and log-concentration, representing both the provisional dosage-mortality curves and the corrected estimates.

Variation Due to	Degrees of Freedom	Based Upon Unweighted Empirical Profits			Based Upon Weighted, Corrected Profits
		Sum of squares	Mean square	F	F
Combined slope for all tests, b_c	1	60.0393	60.0393	527.12	482.62
Differences between daily slopes	6	.9095	.1516	1.33	1.17
Differences between individual slopes	13	2.3243	.1788	1.57	2.60
Deviations from straight lines	40	4.5576	.1139	1	1

The significance of the variations in slope has been judged by comparison with the mean of the squared deviations between the observed probit kills and their expected values as predicted from the 20 individual dosage-mortality curves. These residual $[y^2]$'s were computed as shown at the foot of table 2 and averaged .1139. This mean square measured the experimental error for the experiment as a whole. All mean squares were divided by .1139 to obtain the relative values (F) in the fifth column of table 3. Judging from the variance ratios based upon unweighted, empirical probits, with corrected values only for 100 per cent kill, the 20 individual curves could be represented adequately by a single combined slope of $b_c = 2.583$.

It has been noted in some experiments with insects that the log-probit curve tended to be less steep at the lower mortalities. A small but consistent "curvature" or "break" should be apparent upon inspection of a composite diagram if this were true. For a check upon the scatter

of the observations, the individual curves were shifted horizontally on the x axis until their mean probits fell along a single line passing through the mean probit for all series of $\bar{\bar{y}}=6.217$ with $b_c=2.583$. This could be accomplished by adding to each log-concentration for any given curve a factor equal to $(\bar{y}-\bar{\bar{y}})/b_c$ or $(\bar{y}-6.217)/2.583$, giving the "adjusted" log concentrations plotted on the abscissa of figure 2. It is apparent from the figure that there was no consistent non-linear trend which would warrant shifting to some transformations other than the log-concentration and the probit.

Since deviations from the combined slope were not significant, the chemicals could be compared in terms of the log-concentration killing any selected percentage of insects. For this comparison the log-concentration killing 95 per cent of the aphids (log-LD95) or 6.645 probits seemed the most appropriate, because it both approached the level of mortality of especial interest to the entomologist and at the same time fell but little above the mean probit (6.217) for the experiment. Hence, it did not represent an extrapolation beyond actual experience. The log-LD95 was computed from the mean probit ($\bar{y}$) for the 20 valid series as

$$\text{log-LD95}=\bar{x}+(6.645-\bar{y})/b_c$$
$$=0.45+(6.645-\bar{y})/2.583.$$

These formed the units for comparing the toxicities of the seven chemicals.

COMPUTATION WITH CORRECTED PROBITS AND WEIGHTS.—The qualification that the probits were unweighted, or weighted equally, has been stressed in the above discussion. This assumption may be adopted in estimating provisional dosage-mortality curves, which are essential for calculating corrected probits and weights as has been described elsewhere (Bliss 1938). Improved estimates of the dosage-mortality curve are then computed from the corrected probits and weights. A corrected curve has been calculated for each of the 20 series, starting with the provisional estimates described above. Instead of being weighted equally, the probit mortalities then carried weights varying from 1 to 371, and increasing sharply from higher to median kills. The curves computed by the two methods would not be expected to coincide exactly.

One advantage of the more precise computation is that the agreement between the computed straight line and the observed mortalities can be tested by chi-square. With the present experimental technique, the different pots of infested nasturtiums may have differed in the age distribution and other characteristics of their aphid populations. The number of aphids per pot averaged more than 560. So large a number reduced the sampling error in estimating the percentage of dead aphids on the plants of each pot to a relatively small value and exposed the heterogeneity of the four points about their computed curve. In consequence, chi-square showed disagreement between the observations and the computed curves in comparison with the sampling error in 13 of the 21 series. For all curves, chi-square totalled 349.62 with 40 degrees of freedom, indicating a highly significant heterogeneity for the experiment as a whole. Because of the variation in susceptibility between the aphids on the separate pots, one would prefer to test a larger number of unit colonies of aphids but would not need to base the percentage dead in each colony upon a count of so many individual insects. Unless the density of the aphid colony is in itself a protective condition which the treatment must surmount, this heterogeneity suggests that a large number of potted plants infested with 100 to 150 aphids per unit

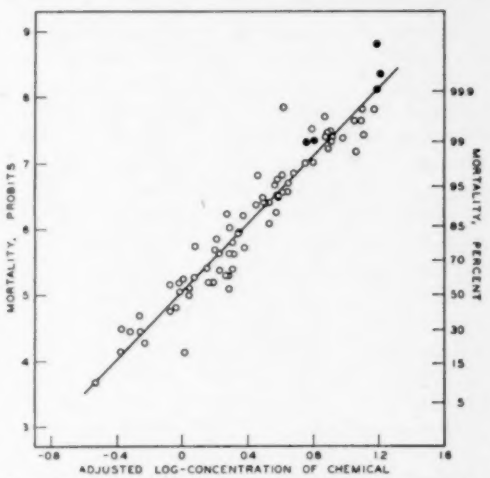

FIG. 2.—Dosage-mortality curves for all tests of the 7 chemicals, following adjustment of the log-concentrations to bring the means for the individual curves into a single straight line. Shaded circles indicate corrected probits for 100 per cent mortality, all other values representing empirical probits.

would be adequate for future studies. If lighter populations would permit a test of all seven chemicals on every day of the experiment, such a change would increase materially the information available from every 100 aphids examined.

Since the probit mortalities were scattered heterogeneously about the individual corrected curves, this same heterogeneity would be expected among the slopes of the different series. The chi-square per degree of freedom for variation between slopes within days and between the combined slopes for the different days has been compared with that within individual curves in the last column of table 3. The variation in slope between chemicals tested on the same day proved to be significant on two of the seven days of the experiment, and these account for the apparently significant variance ratio of 2.60. The slope for nicotine and for di-octyl fumarate tended to be somewhat steeper than that for the glycinonitriles tested at the same time, but the differences were so small and irregular that a comparison of all chemicals on the basis of a single slope would be preferred. The combined slope computed with weights and corrected probits differed by less than 2 per cent from the provisional slope described above.

The dosage-mortality curve computed with corrected probits and weights has proved an adequate measure of toxcity in a large number of experiments and chi-square a sensitive index to the heterogeneity between the component observations. Under laboratory control, relative toxicites based upon parallel dosage-mortality curves fitted to each series in a group have often agreed within the sampling error. Usually, however, fewer individuals have been counted for each percentage than here, so that the sampling error has masked the smaller degree of heterogeneity of a laboratory test. If several doses of two or more poisons were tested simultaneously, each providing a single dosage-mortality curve, the error in comparing the curves had to be based upon the internal consistency of the data and the most effective methods for computing the curves.

In the present study, on the other hand, the large number of aphids on each pot of nasturtiums reduced the sampling errors so as to expose a marked heterogeneity under these semi-field conditions. Conclusions depend primarily, therefore, upon differences between curves and the consistency of these differences rather than upon inferences drawn from the degree of their internal homogeneity. Since the series or curve for each chemical was replicated three times in a design facilitating their comparison, a true error could be determined independently of the internal variation as measured by chi-square. For these and other reasons the less exact but much shorter method of computing the log-LD95 on the assumption of equal weights should give results quite adequate for experiments of the present type. Hence values based upon the so-called "provisional" curves have been used here for the final calculations.

COMPARISON OF THE LD95'S FOR THE SEVEN CHEMICALS.—The concentration in logarithms which would be expected to kill 95 per cent of the aphids (log LD95) has been computed with a single combined slope as described above from the dosage-mortality curve for the four observations of each series and entered in its appropriate position in table 4. The one exception was the estimate for chemical D on July 9. The original observations indicated an aberrant log-LD95 of −.165 for this series, which led to its omission. The experiment has been arranged in balanced incomplete blocks, and the standard methods for analysis depend upon the symmetry of the design. When this balance is destroyed by the loss of an observation, the usual calculation is inapplicable. Instead of changing to a much more complex form of computation, the balance is restored by filling the gap with a value which enables one to complete the analysis in the usual way, with the loss of 1 degree of freedom from the error. The estimation of missing values in balanced incomplete blocks has been described by Cornish (1940), and when applied here, led to an estimated log-LD95 of .396 for chemical D on July 9. With this value inserted in table 4, the calculation followed its normal course.

Yates (1940) has described an improved method for analyzing experiments in balanced incomplete blocks, so that the mean toxicities could be adjusted on the basis of all available information. The method suitable for the analysis of variance of complete, randomized blocks

Table 4.—Toxicity in terms of the log-LD95 (+3.806) for each series.

CHEMICAL	LOG-LD95 ON 7/9	7/10	7/22	7/23	7/24	7/30	7/31	V_s	W_s	Y_s
A	.465	.602		.423				1.510	.412	1.522
B	.343				.652	.536		1.531	.064	1.533
C		.873	.875		1.142			2.890	−1.586	2.844
D	.396[1]		.325				.609	1.330	2.560	1.403
E		.634				.409	.417	1.460	−.694	1.440
F				.987	.989		.931	2.907	−2.562	2.834
G			.330	.426		.309		1.065	1.806	1.117
T_s	1.204	2.109	1.530	1.856	2.783	1.254	1.957	12.693	0	12.639

[1] Determined by missing plot technique

$W_s=(v-k)V_s+(k-1)G-(v-1)S(T_s)=4V_s+2G-6S(T_s)$
$Y_s=V_s+cW_s;$ $v=7,\ k=3$

cannot be used here since only three of the chemicals were tested on any one day. It is the difference between days which needs correction. The adjustment depends upon the balance of treatments between days. Chemical A, for example, was tested with B and D on July 9, with C and E on July 10, and with F and G on July 23. The six chemicals B to G were tested twice without A on the other four days of the experiment. If the toxicity for B to G inclusive averaged less on the three days they were tested with A, than on the four days they were tested without A, then A, too, was probably underestimated and needs ajustment before comparing it with the other chemicals. The same principle is applied to each chemical in turn.

In practice it is easier to add and subtract the marginal totals in obtaining the adjustments for differences between days. The calculation followed that described by Yates for the number of varieties equal to the number of blocks or, in the present case, the number of chemicals equal to the number of days. The sums of the entries for each chemical (V_s) and for each day in table 4 have been entered along the margins of the table, both series of sums totalling 12.693. A multiple of the daily discrepancy between the three days on which a given chemical was tested and the four days on which it was omitted has been computed from the following equation:

$$W_s=(v-k)V_s+(k-1)G-(v-1)S[T_s], \qquad (2)$$

where v is the total number of chemicals and k the number tested on any one day, V_s is the unadjusted total of the log-LD95's for a given chemical s, G is the total of all 21 determinations or 12.693 and $S[(v-1)T_s]$ is the sum of all log-LD95's on the three days chemical s was tested. For chemical *A*, for example, $W_s=4(1.510)+2(12.693)-6(1.204+2.109+1.856)=.412$, and the values of W_s for the remaining chemicals *B* to *G* were computed similarly. Their total, $S(W_s)=0$, veryifying the calculation. These values have been used both to isolate the effect of differences between days by an analysis of variance and later to correct the total log-LD95's for each chemical.

The analysis of variance in table 5 separated the errors in the experiment into two components, that between days and that within days. The sum of squares in the first row $[V_s^2]$, was computed from the totals, V_s, for the seven chemicals, ignoring days, by the formula

$$[V_s^2]=\frac{S(V_s^2)}{k}-\frac{G^2}{N}, \qquad (3)$$

where $S(V_s^2)$ stands for the sum of the squares of V_s, k is the number of replications for each chemical as well as the number tested on any one day, and N the total number of log-LD95's. Substituting the values from table 4, $[V_s^2]=(1.510^2+1.531^2+\cdots+1.065^2)/3-12.693^2/21=1.14850$, the first entry in table 5. The sum of squares between days, eliminating chemicals or treatments, was computed from the column W_s as

$$[W_s^2]=\frac{S(W_s^2)}{kv(v-k)(k-1)}, \qquad (4)$$

where the symbols have the same meaning as before. Numerically $[W_s^2]=(.412^2$

Table 5.—Analysis of variance for separating variation between days from remainder.

Variation Due to	Degrees of Freedom	Sum of Squares	Mean Square
Chemicals, ignoring days, from V_s	6	1.14850	
Days, exclusive of chemicals, from W_s	6	.11637	.019395 = A′
Error within days and chemicals	7	.08132	.011617 = B′
Total	19	1.34619	

$+ .064^2 + \cdots + 1.806^2)/(3)(7)(7-3)(3-1) = 19.54995/168 = .11637$. The total sum of squares $[y^2]$ was determined as in any analysis of variance by summing the squares of the individual entries and subtracting a correction for the mean or

$$[y^2] = S(y^2) - \frac{G^2}{N}, \qquad (5)$$

where y is the individual log-LD95, giving the numerical result of $[y^2] = (.465^2 + .343^2 + \cdots + .931^2) - 12.693^2/21 = 1.34619$. To obtain the experimental error within days, the sums of squares for the first two items were subtracted from total $1.34619 - 1.14850 - .11637 = .08132$. The sums of squares between days and within days, excluding differences between chemicals, were then divided by their respective degrees of freedom to obtain mean squares of .01940 ($=A'$) and .01162 ($=B'$) respectively. Quite evidently the variation from one log-LD95 to another between days exceeded that within days, so that adjusting the estimated toxicity of each chemical for differences between days should increase its reliability.

The adjustment for differences between days was computed from the mean square for the error between days (or blocks), A', and that within days, B'. The coefficient, c, for adjusting the original sum of the three log-LD95's for each chemical, V_s, is given by the equation:

$$c = \frac{A' - B'}{v(k-1)A'}, \qquad (6)$$

and the adjusted Y_s is then equal to

$$Y_s = V_s + c\,W_s, \qquad (7)$$

where all other symbols have their previous significance. Since the number of chemicals (or treatments) equalled the number of days (or blocks) and the number of repetitions the number tested on any one day, Yates' equations for the adjustment could be reduced to the simple form in equation (6). Each Y_s in table 4 represented the sum of three determinations and was divided by 3 to obtain the final estimate of $\bar{y}_s$ for the log-LD95 for each chemical. Substituting the numerical values from table 5, the coefficient c was computed as

$$c = \frac{.01940 - .01162}{7(3-1)\,.01940} = .02865.$$

The adjusted total for chemical A was $Y_s = 1.510 + (.02865)(.412) = 1.522$, and its mean log-LD95, $\bar{y}_s = 1.522/3 = .507$. The final estimates for the other chemicals were computed similarly.

The standard error of each adjusted mean involves certain approximations, which are discussed by Yates (6). For experiments in balanced incomplete blocks where equation (6) is applicable, the standard error of the mean may be computed as

$$s_{\bar{y}_s} = \sqrt{\frac{B'[k(v-1)A' - (v-k)B']}{vk(k-1)A'}} \qquad (8)$$

where all symbols have the same meaning as before. For comparing two means, it is convenient to compute the

$$\text{"just significant difference"} = \sqrt{2}\,t s_{\bar{y}_s}$$

where t is read for the required level of significance from tables such as table 3 in Fisher & Yates (1935), with as many degrees of freedom as in the error within days and chemicals or $v(k-2)+1$. Substituting from table 5, the standard error of each mean proved to be

$$s_{\bar{y}_s} = \sqrt{\frac{.01162[3(7-1).01940 - (7-3).01162]}{(7)(3)(3-1)(.01940)}} = 0.0657.$$

In the present experiment one log-LD95 had to be replaced by a computed value, so that there were 7 instead of 8 degrees of freedom in the error. The value of t for $n=7$ and $P=.05$ as read from the table is 2.365. A difference between 2 log-LD95's less than $1.414 \times 2.365 \times 0.0657 = 0.220$ would not be considered significant.

The adjusted mean log-LD95 for the standard contact insecticide, nicotine has

been listed first in table 6 and followed in order of increasing toxicity by the six new chemicals. The two amyl-phenyl glycinonitriles required a significantly larger concentration than the other five materials in the experiment. The dibenzyl, benzyl-phenyl and diphenyl glycinonitriles differed less in toxicity than the standard error of the determination. The 50–50 mixture of diphenyl glycinonitrile and dioctyl fumarate required the smallest concentration of all to produce a 95 per cent kill, although not enough less than diphenyl glycinonitrile alone for the difference to be established as statistically significant. In the last column of table 6 the log-LD95's have been transformed to the concentrations, in parts per 1,000, which killed 95 per cent of the aphids under the conditions of the present experiment.

Table 6.—Relative toxicity of seven chemicals to Aphis rumicis in contact sprays, corrected for differences between days.

	Chemical	Log-LD95 (+3.806)	LD95 Parts per 1000
A	Nicotine, Standard 40% solution	.507	.501
	Pure base	(.109)	(.200)
C	Isoamyl phenyl glycinonitrile	.948	1.384
F	Mixed amyl-phenyl glycinonitrile	.945	1.374
B	Dibenzyl glycinonitrile	.511	.506
E	Benzyl phenyl glycinonitrile	.480	.471
D	Diphenyl glycinonitrile	.468	.458
G	50–50 Mixture diphenyl glycinonitrile and dioctyl fumarate	.372	.367
	Standard error	.066	
	Difference between chemicals for P = .05	.220	

SUMMARY.—Following preliminary tests with more than 400 chemicals in contact sprays against *Aphis rumicis*, five substituted glycinonitriles and a mixture of one of the five with dioctyl fumarate were selected for quantitative comparison with a standard nicotine insecticide. Sprays of four concentrations of each compound were replicated on three different days in such a way that every compound was tested once on the same day with every other compound. By a simplified procedure, which is described, parallel dosage-mortality curves in terms of log-concentrations and empirical probits were computed for the three tests of all seven chemicals and from them the log-concentration killing 95 per cent of the aphids. The mean log-LD95 for each chemical was then corrected for differences in the overall susceptibility of the aphids between days. The calculation of these relative toxicities and their experimental errors is described in full. The two amyl phenyl glycinonitriles were less than half as toxic as the dibenzyl, benzyl phenyl and diphenyl glycinonitriles, which compared favorably with *Black Leaf 40*, a standard 40 per cent solution of nitotine.—2-13-42.

LITERATURE CITED

Bliss, C. I. 1935. The calculation of the dosage-mortality curve. Appendix by R. A. Fisher. Ann. Appl. Biol. **22:** 134–67.

Bliss, C. I. 1938. The determination of the dosage-mortality curve from small numbers. Quart. Jour. Pharm. Pharmacol. **11:** 192–216.

Bliss, C. I., and H. P. Marks. 1939. The biological assay of insulin I. Some general considerations directed to increasing the precision of the curve relating dosage and graded response. Quart. Jour. Pharm. Pharmacol. **12:** 82–110.

Cornish, E. A. 1940. The estimation of missing values in incomplete randomized block experiments. Ann. Eugenics. **10:** 112–8.

Fisher, R. A., and F. Yates. 1938. Statistical tables for biological, agricultural and medical research. London. Oliver and Boyd, 1–90.

Yates, F. 1940. The recovery of inter-block information in balanced incomplete block designs. Ann. Eugenics **10:** 317–25.

Youden, W. J. 1940. Experimental designs to increase accuracy of greenhouse studies. Contrib. Boyce Thompson Inst. **11:** 219–28.

American Association of Economic Entomologists

Annual Meeting

Hotel New Yorker, New York City

December 29, 30, and 31, 1942

The Influence of Lime on the Toxicity of Lead Arsenate to Cabbage Worms[1]

G. E. R. Hervey and G. W. Pearce,[2] *New York State Agricultural Experiment Station, Geneva*

Lead arsentate dust has been extensively used for the control of cabbage worms on Danish cabbage and on domestic cabbage grown for the manufacture of sauerkraut in western New York. The principal reason for the use of this material is its cheapness in comparison with rotenone and pyrethrum dusts, although it is somewhat less effective. For a number of years hydrated lime has been used as the diluent or carrier for the lead arsenate. This mixture has good dusting properties and both materials are readily available to cabbage growers. Recently, however, comparisons of lead arsenate-lime mixtures with lead arsenate alone and with certain other diluents have shown that the lime combinations are invariably less efficient in cabbage worm control. As a result of such observations, the use of lime in arsenical dusts for cabbage insect control has been largely replaced by inert, diluents in this state. In this paper, the experimental evidence for the change in the recommendation is presented. The data obtained also have interest in connection with the general question of the effect of lime on the insecticidal efficiency of arsenicals.

Experiments were carried out in 1940 and 1941 in which control data were collected from plats treated with lead arsenate alone and in combination with lime,[3] *Loomkill Talc*, *Pyrax ABB* and *Bancroft Clay*. As a basis for comparing the efficiencies of the different treatments, arsenical residue analyses were made from samples taken from the treated plants at intervals during the season.

Field Technique.—A commercial planting of Danish type cabbage was used for the experiments in both 1940 and 1941. The insects against which the treatments were directed were the imported cabbage worm, *Pieris rapae* L., and the cabbage looper, *Autographa brassicae* Riley. Both species were very abundant from the middle of July until the end of the season in 1940. In 1941 there was a rather light infestation of the imported cabbage worm and practically no cabbage looper.

The plat size used in these experiments consisted of four rows of cabbage 60 feet in length. This area included approximately 160 plants. They were replicated four times and arranged in randomized blocks. The dust treatments were applied with a rotary hand duster and the sprays with a knapsack sprayer. Three applications of the materials were applied at approximately two-week intervals during the period of maximum insect activity during July and August. All the treatments included here were applied by the same operator and always on the same day. By following this method the amount of each material applied to each plat was kept reasonably uniform.

The dusts used in these experiments were all made up to contain 25 per cent lead arsenate and 75 per cent diluent. In the sprays the lead arsenate and hydrated lime were both used at the rate of 5 pounds to 100 gallons of water. Skimmilk powder, at the rate of 2 pounds to 100 gallons of the mixture, was used as a spreader for the sprays in 1940 while Grasselli Spreader-Sticker was used at the rate of 6 ounces to 100 gallons for the same purpose in 1941. The lead arsenate-*Pyrax*-soy-bean oil dust used in 1941 contained the usual proportions of arsenical and diluent with the addition of 2 pints of crude soy-bean oil in 100 pounds of dust.

The method used to estimate the comparative value of the treatments consisted of determining the number of plants in each of three categories arbitrarily established on the basis of the degree of insect injury. These categories were designated "clean," "moderate" and "severe" in the 1940 experiment and "clean," "light" and "moderate" in 1941. The grading of the plants was done independently by two observers and their results were averaged. Such averages were used to calculate the percentage of plants falling into each injury classification. Two injury measurements were made in 1940. The first was

[1] Approved by the Director of the New York State Agricultural Experiment Station for publication as Journal Paper No. 503.

[2] The writers wish to acknowledge the assistance of Dr. A. W. Avens of the New York State Agricultural Experiment Station in the collection and analysis of the residue samples.

[3] High calcium hydrated lime. *Loomkill Talc* obtained from the Voomis Talc Corporation. *Pyrax ABB* supplied by the R. T. Vanderbilt Company. *Bancroft Clay* supplied by the United Clay Mines Corporation.

taken on September 13 and was based on the degree of insect feeding on the leaves surrounding the head. The second record was made on November 6 when the cabbage was harvested and after the outside leaves had been removed. The classification in this case was based on the holes or tunnels in the underside of the head made by the cabbage looper and is, therefore, chiefly an index to the abundance of this insect. In 1941, the counts were made on September 30, all insect activity having ceased by this time. In this case the category "severe" was not used since there were no plants injured seriously enough to be included in this group.

RESIDUE ANALYSES.—Under the usual conditions of treating cabbage with lead arsenate sprays or dusts the residues tend to be highly irregular in their distribution on the leaf surfaces. For this reason, a potentially large sampling error is involved in making residue analyses from cabbage leaves. Since it is impractical to eliminate such an error by taking exceedingly large samples for analysis, it was necessary to develop a sampling technique which would produce the same result using relatively small amounts of leaf surface per sample. Preliminary tests indicated that a sample of 100 disks taken with cork borers ranging from five-eighths to 1 inch in diameter, depending on the residue load, would contain amounts of arsenic or lead which could be conveniently handled by the usual analytical methods. In taking a sample, a single disk was cut out of one of the crown leaves from each of 100 individual plants. When cutting disks, care was taken to select leaf areas which had a rather uniform deposit. Thus, those areas containing clumps of the dust or those which had not been hit with the spray or dust were avoided as much as possible.

By following this procedure it was found that the sampling error could be kept sufficiently small so that a comparison of residue loads from the different treatments under study could be logically made. Samples were taken in duplicate by two individuals for most of the work reported here. The deviation of the residue load from the mean of such duplicates averaged about 10 per cent.

Analyses of both arsenic and lead were made in some instances. However, only the values obtained for arsenic are used in this report. Results are calculated on the basis of the area of top leaf surface contained in a sample. This was done because little or no residue occurred on the under side of the leaves.

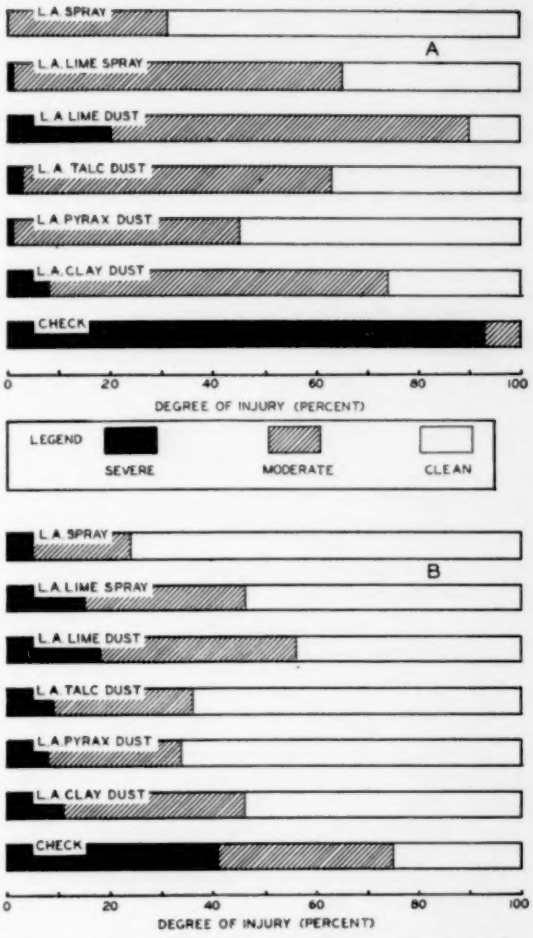

FIG. 1.—A comparison of the degree of insect injury to cabbage plants treated with various lead arsenate (LA) mixtures in 1940. A. Record taken September 13. B. Record taken November 6.

The residues were removed from each sample of disks by washing with hot 1 to 3 HNO_3 followed by three or more washings with distilled water, all washings being transferred to a kjeldahl flask. Twenty milliliters of concentrated H_2SO_4 were added and the mixture digested. The arsenic was then distilled and titrated according to a slight modification of the Bromate method (1935). In some instances the entire sample was wet-ashed but this procedure was discarded in favor of the above because the relatively large

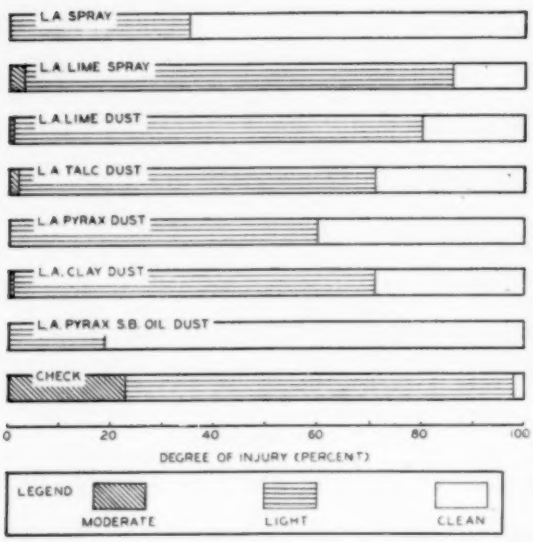

FIG. 2.—A comparison of the degree of insect injury to cabbage plants treated with various arsenical mixtures in 1941.

amount of calcium in the cabbage leaves caused severe bumping during digestion. Moreover, experiments showed that essentially 100 per cent of the residue was recovered by the HNO_3 washing procedure.

RESULTS AND DISCUSSION.—In figure 1 the degree of insect injury observed in the various experimental plats of 1940 is shown graphically. Part A represents the record taken on September 13 and Part B the record on November 6. Figure 2 is a graphical presentation of the insect damage occurring in the test plats of 1941.

The significance of the control data is believed to be relatively high. This is shown in part by the fact that the three graphs of injury measurements exhibit the same order of relative efficiencies for the treatments. It is also clear from the figures that in all instances the presence of lime in sprays or dusts reduced the control of the insects in comparison with lead arsenate used alone or used with the other diluents studied. Three treatments appear to be outstanding in control efficiency. These are the lead arsenate spray, without lime, lead arsenate-*Pyrax* dust, lead arsenate-*Pyrax*-soy-bean oil dust. The clay and talc dusts tend to be somewhat less effective than these three but are superior to any of the lead arsenate-lime dusts and equal to or better than the lead arsenate-lime sprays.

A summary of the arsenical residue analyses is presented in tables 1 and 2, representing results from the 1940 and 1941 tests, respectively. In order to simplify the presentation of the residue data, only the average initial loads and the average load ten days after treatment are shown in table 1. The averages were calculated from the analyses of samples taken the same day and ten days after each of the three applications. The residue analyses given in table 2 were obtained from samples taken after the third application only.

Typical weathering characteristics of the sprays and dusts are shown by the curves in figure 3. These curves were plotted from residue analyses obtained for the 1940 experiments. In general, they are representative of the curves obtained for the other treatments with the exception of the dusts containing *Pyrax* with and without soy-bean oil studied in 1941 (see table 2). The lead arsenate-*Pyrax*

Table 1.—Average residue loads on cabbage foliage after treatment with lead arsenate mixtures, 1940.

	MG. As_2O_3 PER 100 SQ. IN. OF TOP LEAF SURFACE	
	Average initial deposit	Average deposit 10 days after application
Lead arsenate spray	7.53	2.58
Lead arsenate-lime spray	7.12	2.49
Lead arsenate-lime dust	5.70	0.14
Lead arsenate-talc dust	8.35	0.25
Lead arsenate-*Pyrax* dust	7.79	0.24
Lead arsenate-clay dust	6.38	0.23

Table 2.—Residue loads on cabbage foliage after treatment with lead arsenate mixtures, 1941.

	MG. As_2O_3 PER 100 SQ. IN. TOP LEAF SURFACE		
	Initial deposit	10 days after treatment	16 days after treatment
Lead arsenate spray	5.58	2.53	1.88
Lead arsenate-lime spray	6.18	4.00	2.38
Lead arsenate-lime dust	6.23	0.63	—
Lead arsenate-talc dust	8.16	0.89	—
Lead arsenate-*Pyrax* dust	7.36	1.60	1.80
Lead arsenate-clay dust	6.55	0.70	—
Lead arsenate-*Pyrax*-soy-bean oil dust	13.65	5.55	6.00

dust gave definitely better resistance to weathering in 1941. The addition of soybean oil to this dust raised the adhesive properties of it greatly. As would be expected, the sprays show more adhesive powers than the lime, talc, clay or *Pyrax* dusts. Figure 3 shows about the average difference.

A study of both the insect control and residue data presented strongly indicates that the reduction in control efficiency of the treatments containing lime cannot be accounted for on the basis of differences in arsenical residue loads. Although the residue loads observed for the talc, clay and *Pyrax* dusts tend to be somewhat higher than the lime dusts, it is believed that this difference is not sufficient to cause the large difference observed in insect control. Thus, if the difference in load between lead arsenate-lime and lead arsenate-talc dusts (tables 1 and 2) accounts for their difference in effectiveness (figs. 1 and 2) then one should expect that the lead arsenate-lime spray should be far superior to the lead arsenate-talc dust because of its much higher residue load. This is clearly not in accord with the experimental facts. Further evidence that the differences in residue load do not account for the effect of lime on efficiency is seen in the data on sprays. Here, the residue load is essentially the same but there is a large difference in efficiency. The pronounced superiority of the lead arsenate-*Pyrax*-soy-bean oil dust over all the other treatments is probably accounted for by its property of depositing a much higher initial load of great uniformity in distribution which offers high resistance to weathering.

It seems clear from the evidence presented that the presence of lime in lead arsenate sprays or dusts caused a reduction in the toxicity of the arsenical towards the insects considered. Evidence that this effect may occur in the case of other insects is apparently limited as is indicated by the widespread use of lime with lead arsenate in many spray schedues.

The fundamental explanation of the phenomena observed offers considerable difficulty. However, it is reasonable to assume that it is associated with the commonly observed fact that calcium arsenates are frequently less toxic than lead arsenate, particularly in the case of Lepidopterous larvae. Thus, Norton & Hansberry (1941) observed this in the case of the silkworm. Previous work by the senior author has also shown calcium arsenate to be less effective than lead arsenate in controlling cabbage insects. Some typical results of such a comparison are shown in table 3.

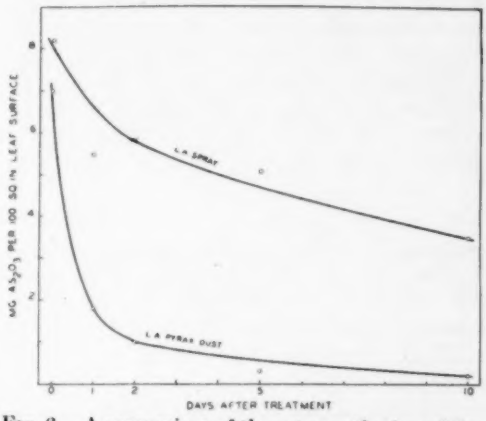

FIG. 3.—A comparison of the rate weathering of the residues of a lead arsenate spray and a dust on cabbage plants.

It is well known that many calcium compounds readily react with lead arsenate to produce various amounts of calcium arsenates. The simultaneous presence of lime (or calcium carbonate) and lead arsenate in the insect's gut would undoubtedly lead to the formation of at least some calcium arsenate. In any event, calcium, lead and arsenic in the form of ions would probably be absorbed through the gut. Thus, conditions for the formation of complex ions containing calcium and arsenic are potentially present. As suggested by Norton & Hansberry (1941), such ions may have less toxicity than those normally occurring from the absorption of lead arsenate alone While

Table 3.—A comparison of lead arsenate and calcium arsenate-hydrated lime dusts for the control of cabbage worms, 1937. Five applications.

MATERIAL	DEGREE OF INJURY AT HARVEST			AVERAGE YIELD POUNDS PER ACRE
	Per Cent clean	Per Cent mod.	Per Cent severe	
Lead arsenate-lime dust	47.6	41.1	11.3	36842
Calcium arsenate-lime dust	18.7	43.7	37.7	30976
Check	4.7	26.3	69.1	30354

many hypotheses are possible, the actual mechanism involved is only vaguely suggested at this time. Work has already been initiated by the writers which may throw additional light on this subject. Irrespective of the explanation for the phenomena observed, the evidence appears to be increasing that the presence of lime in arsenical sprays or dusts may be an undesirable practice from the standpoint of controlling a variety of insects.

SUMMARY.—Results of two years' experiments for the control of cabbage worms with various lead arsenate treatments are presented. Data on the comparative effectiveness of dusts containing hydrated lime *Loomkill Talc*, *Pyrax ABB* and *Bancroft Clay* as diluents and lead arsenate sprays with and without lime were obtained. All treatments containing lime showed markedly lower control efficiencies. Data on the arsenical residue loads of the various treatments are presented to show that the effect of lime on control is not accounted for by differences in arsenical load but to an actual reduction in the toxicity of the lead arsenate. A brief discussion of the possible mechanism of this observation is included.—**4-6-42.**

LITERATURE CITED

Methods of Analysis. 1935. Association of Official Agricultural Chemists, Washington, D. C. P. 373.

Norton, L. B., and Roy Hansberry. 1941. Radioactive tracer methods for determination of the disposition of arsenic in the silkworm. JOUR. ECON. ENT. **34**(3): 431–7.

Mosquito Studies in Military Establishments in the Seventh Corps Area During 1941[1]

STANLEY J. CARPENTER, *Camp Robinson, Ark.*[2]

Malaria presents a major problem in the establishment and maintenance of military training camps and other war establishments in many areas in the Southern United States. The fact that malaria is seldom a killing disease but one that accounts for many sick days makes it necessary for us to take every precaution to protect our men engaged in military training and war industries from mosquitoes which transmit this disease. In the Army the Medical Department provides the technical supervision for the mosquito control program in which an attempt is made to control both disease-bearing species and those species of importance to man only from the standpoint of discomfort caused by their biting.

This paper contains descriptions and summaries of mosquito investigations made from May through November, 1941, in Camp Robinson, Arkansas, and summaries of mosquito surveys made in Jefferson Barracks, Fort Leonard Wood and Camp Crowder, Missouri, and in Camp Chaffee, Arkansas. Frequent collections of both larval and adult specimens of mosquitoes were identified from Fort Leonard Wood throughout the year.

Entomological studies are essential for the satisfactory conduction of any mosquito control program. Prior to the commencement of actual control work in an area, an adequate survey should be made to determine the exact nature of the mosquito problem and continuous entomological investigations are necessary while the control measures are in operation in order that maximum benefits may be derived from the work.

COLLECTION METHODS.—Adult mosquito collections were obtained in the Camp Robinson Area by the use of New Jersey mosquito traps, by hand collecting in diurnal shelters including tents and by collecting adults by hand while biting or attempting to bite. Larval collections were obtained from typical mosquito breeding places of the different species throughout their breeding season. Adult specimens and fourth stage larvae were identified in the laboratory. Pinned adult specimens and permanent mounts of larvae and male hypopygia of the different species collected during the year in the

[1] This paper has been granted priority because of its potential value to the armed forces.

[2] Captain, Sanitary Corps, U. S. Army, Office of the Surgeon, Camp Joseph T. Robinson Arkansas.

area are in the permanent collections at Camp Robinson.

Seven electrically operated New Jersey mosquito traps were operated during five nights of each week from July through December in the cantonment area of Camp Robinson for the purpose of sampling the mosquito population and for measuring the densities of certain disease-bearing and pest species of mosquitoes. Twenty-five species of mosquitoes were collected during the year in traps in Camp Robinson. Table 1 gives a summary of trap collections from July to November 15.

Table 1.—Mosquito trap collections in Camp Joseph T. Robinson, Arkansas, during 1941.

Mosquito Species	July	August	September	October	November	Total
Anopheles						
quinquemaculatus	43	52	144	40	4	283
punctipennis	4	2	5	9	5	25
crucians	5	0	2	4	1	12
barberi	1	2	2	1	0	6
Culex						
quinquefasciatus	0	94	152	366	22	634
restuans	92	0	9	65	1	167
salinarius	33	122	29	27	6	217
tarsalis	0	1	22	49	25	97
apicalis	2	1	8	1	6	18
erraticus	6	14	23	7	1	51
Aedes						
vexans	48	17	58	785	104	1012
triseriatus	1	5	1	1	0	8
dupreii	6	0	3	0	0	9
atlanticus	0	1	4	0	0	5
cinereus	0	0	1	0	0	1
tricitatus	0	0	0	1	0	1
Psorophora						
columbiae	300	330	240	66	0	936
ferox	1	1	9	7	0	18
discolor	38	28	38	8	0	112
ciliata	0	2	8	4	0	14
cyanescens	0	1	0	0	0	1
Theobaldia						
melanura	0	3	1	0	0	4
inornata	0	0	0	36	68	104
Uranotaenia						
sappharina	11	22	85	55	0	173
Orthopodomyia						
signifera	2	0	1	0	0	3
No. Damaged	14	6	7	3	3	33
Total	608	704	852	1535	246	3945
Days of Operation	93	150	147	152	90	632
Ave. Daily Catch	6.5	4.7	5.8	10.1	2.7	6.2
	Per Cent					
[1]*Aedes*, and *Psorophora*	64.6	54.0	43.4	56.7	42.3	53.5
Anopheles quadrimaculatus	7.1	7.4	16.9	2.6	1.6	7.2

[1] Temporary pool breeders.

There have been differences of opinion among entomologists as to the value of the New Jersey mosquito trap as a device for measuring densities of certain important species including *Anopheles quadrimaculatus* Say. It is the opinion of the writer that we should not expect a single method such as trap operations or hand catches from diurnal shelters to give a satisfactory picture of the mosquito problem in an area but that investigations should at least include mosquito trap operations, hand catches in diurnal shelters and while biting and larval collections from different types of mosquito breeding places throughout the entire area.

Adult mosquito collections were obtained at weekly intervals in the Camp Robinson Area during the summer in ten diurnal shelters consisting of culverts, privies, spring houses and hollow trees. There is a close correlation in the weekly averages of *Anopheles quadrimaculatus* taken in traps and in diurnal shelters during 1941 as shown in figure 1. Rainfall occurred on four nights during the first week in September and may have caused the sharp reduction in the numbers taken in traps during this period.

A total of 144 mosquito collections representing 14 species was taken resting in diurnal shelters in Camp Robinson and vicinity during the year. *Anopheles quadrimaculatus*, *Anopheles punctipennis* Say, *Culex quinquefasciatus* Say, *Culex restuans* Theob., *Culex salinarius* Coq., *Culex erraticus* D. & K., were common in diurnal shelters while *Culex apicalis* Adams, *Culex peccator* D. & K., *psorophora ferox* Humb., and *Uranotaenia sappharina* O.-S. were taken on rare occasions in daytime resting places. Fifteen collections representing seven species of mosquitoes including *A. quadrimaculatus*, *A. punctipennis*, *Aedes vexans* Meigen, *P. columbiae* D. & K., *P. ferox*, *P. horrida* D. & K., and *P. varipes* Theob. were collected while biting or attempting to bite in the Camp Robinson Area. One specimen of *Aedes aegypti* L., a species taken in a diurnal shelter was not taken in mosquito traps during the year and two species, *P. horrida* and *P. varipes*, which were collected while biting were not collected in traps.

A total of 263 larval collections representing 20 species was taken in the larva stage in the Camp Robinson Area. The locations of all mosquito breeding places found were marked on a map of the camp area, collection date was recorded and a brief statement of control work required

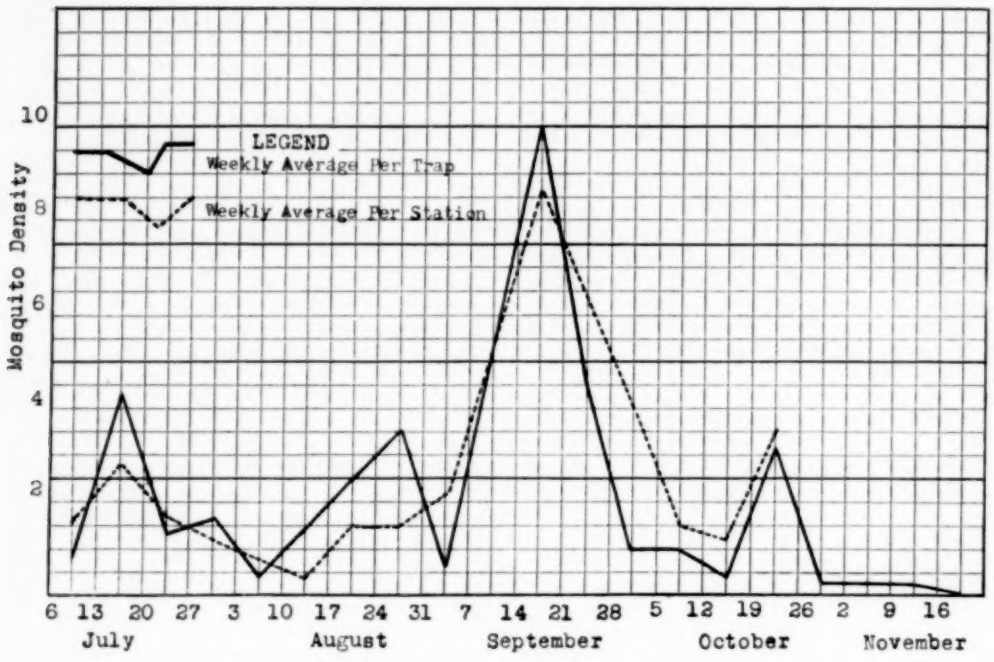

FIG. 1.—Trap and hand collections of *Anopheles quadrimaculatus*.

for correction was included in the record.

PREVALENCE IN CAMP ROBINSON.—The forces of nature combined to make the problem of mosquito control difficult in the Camp Robinson Area during the year. Precipitation was above normal in June, July, October and December. Rainfall was frequent during several periods so as to provide ideal conditions for heavy productions of temporary pool breeding species of *Aedes* and *Psorophora* during portions of the season.

Table 2 shows the occurrence of the 31 species of mosquitoes taken in Camp Robinson as indicated by all the different collection methods used. *Anopheles quadrimaculatus, Culexquinquefasciatus, Aedes vexans,* and *Psorophora columbiae* were troublesome species during the year. *A. punctipennis, C. restuans, C. erraticus, P. ferox, P. discolor* Coq., *Theobaldia inornata* Will., and *Uranotaenia sappharina* were common in the area but were never present in sufficient numbers to be of much importance. Other species shown in Table 1 were scarce in the area.

A total of 134 trap and hand collections of adults and larvae representing 16 species of mosquitoes was obtained in Camp Chaffee, Arkansas, in a survey conducted during September and October. Among the *Anopheles* species, *A. punctipennis* was dominant in this area.

Prior to this study there were published records of 42 species of mosquitoes in Arkansas. During 1941 the writer obtained records of two additional species consisting of a female specimen of *Aedes trivittatus* Coq., taken in a trap in Camp Robinson during the night of October 23, 1941, and a female specimen of *Anopheles pseudopunctipennis* Theob. taken in a diurnal shelter in Texarkana on September 30, 1941. A female specimen of *Aedes grossbecki* D. & K. was taken in a trap in Camp Robinson during the night of April 24, 1942. These additional records increase to 45 the number of species now known to occur in Arkansas.

MISSOURI COLLECTIONS.—Six mosquito traps of the New Jersey type were operated in Fort Leonard Wood during July, August, September and October. Several hand catches of adult mosquitoes and larval collections were obtained by the writer and local personnel in Fort Wood during the year. Eighteen species of mosquitoes representing 205 collections and 551 specimens were identified by the writer from Fort Leonard Wood in 1941.

Table 2.—Numerical importance of the species of mosquitoes of Camp Joseph T. Robinson, Arkansas, as shown by larval and adult collections.

Species	Adults			Larvae			Total		
	Tot. No.	Per Cent	No. Cols.	Tot. No.	Per Cent	No. Cols.	No.	Per Cent	Tot. No. Cols.
A. quadrimaculatus	566	11.5	200	142	11.2	37	708	11.5	237
A. punctipennis	78	1.5	47	147	11.6	43	225	3.6	90
A. crucians	14	0.3	13	3	0.2	2	17	0.3	15
A. barberi	6	0.1	5	0	0.0	0	6	0.1	5
C. quinquefasciatus	898	18.4	211	194	15.2	26	1092	17.7	237
C. restuans	201	4.0	52	141	11.0	34	342	5.5	86
C. salinarius	218	4.4	52	26	2.0	9	244	4.0	61
C. tarsalis	97	1.9	62	0	0.0	0	97	1.6	62
C. apicalis	22	0.4	16	27	2.1	16	49	0.8	32
C. erraticus	62	1.2	54	109	8.6	22	171	2.8	76
C. peccator	9	0.2	7	0	0.0	0	9	0.2	7
A. vexans	1189	24.3	213	89	7.0	9	1278	20.7	222
A. triseriatus	10	0.2	10	9	0.7	2	19	0.3	12
A. dupreii	12	0.2	10	31	2.4	2	43	0.7	12
A. atlanticus	15	0.3	9	0	0.0	0	15	0.2	9
A. cinereus	2	0.05	1	0	0.0	0	2	0.03	1
A. trivittatus	1	0.05	1	0	0.0	0	1	0.02	1
A. aegypti	4	0.08	4	10	0.8	2	14	0.2	6
P. columbiae	946	19.3	265	129	10.1	21	1075	17.4	286
P. ferox	63	1.3	31	66	5.2	6	129	2.1	37
P. discolor	117	2.3	73	9	0.7	3	126	2.0	76
P. ciliata	14	0.3	12	15	1.2	4	29	0.5	16
P. cyanescens	1	0.05	1	0	0.0	0	1	0.02	1
P. horrida	9	0.2	4	0	0.0	0	9	0.2	4
P. howardii	0	0.0	0	24	1.9	4	24	0.4	4
P. varipes	2	0.05	1	0	0.0	0	2	0.03	1
T. melanura	6	0.1	2	0	0.0	0	6	0.1	2
T. inornata	137	2.8	82	0	0.0	0	137	2.2	82
U. sappharina	189	3.9	82	51	4.0	14	240	3.9	96
O. signifera	3	0.6	3	42	3.3	6	45	0.7	9
M. septentrionalis	0	0.0	0	10	0.8	3	10	0.2	3
Totals	4891	100.0	1516	1274	100.0	263	6165	100.0	1788

Nineteen collections of mosquito larvae and adults containing six species were obtained by the writer in Jefferson Barracks during August. Seventy-one hand and trap collections of adults and larvae representing 12 species of mosquitoes were obtained in Camp Crowder, Missouri, during a mosquito survey conducted in September. Collections of mosquitoes obtained in Missouri camps consisting of Camp Crowder, Jefferson Barracks, and Fort Leonard Wood during 1941, yielded 20 species including the following: *Anopheles quadrimaculatus*, *A. punctipennis*, *Culex pipiens* Linn., *C. quinquefasciatus*, *C. restuans*. *C. salinarius*, *C. tarsalis*, Coq., *C. erraticus*, *C. apicalis*, *Aedes triseriatus* Say, *A. trivittatus*, *psorophora columbiae*, *P. discolor*, *P. ciliata* Fab., *P. cyanescens* Coq., *Theobaldia melanura* Coq., *T. inornata*, *Orthopodomyia signifera* Coq. and *Uranotaenia sappharina*.

SUMMARY.—This paper contains descriptions of different methods used for sampling adult and larval densities of mosquitoes in Army camps in the Seventh Corps Area during 1941. Summaries of collections taken by the different methods are given. Mosquito traps of the New Jersey type compared favorably with hand collection methods for measuring adult densities of *Anopheles quadrimaculatus*. Four species of mosquitoes including *A. quadrimaculatus*, *C. quinquefasciatus*, *A. vexans*, and *P. columbiae* were present in sufficient numbers in Camp Robinson during 1941 to constitute a major problem. The peak in the production of *A. quadrimaculatus* in Camp Robinson and vicinity occurred during September.

A total of 20 species of mosquitoes was taken during mosquito surveys in Army camps in Missouri during the year. Specimens of *Anopheles quadrimaculatus* were obtained in each of these areas.—5-16-42.

Lethal Temperatures for *Dermacentor andersoni* Stiles and Other Ticks in British Columbia[1]

G. Allen Mail, *Livestock Insect Laboratory, Kamloops, B. C.*

The most important North American tick from the viewpoint of disease transmission is *Dermacentor andersoni* Stiles. It is the chief vector of Rocky Mountain spotted fever and tick paralysis and also is incriminated in the transmission of tularaemia and certain obscure virus diseases of man and animals. Experimentally, at least, it has been proved capable of transmitting equine encephalomyelitis, although the virus of the disease has not been recovered from ticks in nature.

Dermacentor andersoni Stiles is rather widely distributed over Western North America. In Canada its western limit is the Coast Range of mountains. There are one or two scattered records west of this boundary, but these, so far, are insufficient to denote an established habitat. The northern boundary of its range roughly could be delimited by a line from the Coast Range due east to Prince George, B. C., then south-east of Moose Jaw, Saskatchewan, thence south to the international boundary. Within this region are large areas where the tick is scarce or absent, but with these exceptions it is abundant and appears to be increasing yearly in numbers.

Dermacentor andersoni Stiles has a complex life-cycle, which, under unfavorable conditions, may occupy three years. This means that during one winter at least, and possibly two, the tick must hibernate. Little is known about the temperatures to which ticks are subjected during hibernation and nothing has been published on the lethal low temperatures for ticks. Notwithstanding the fact that low temperature has been demonstrated frequently to be the limiting factor in the distribution of certain other arthropods, it is not intended in this brief paper to suggest that it is so with ticks, although undoubtedly in the ecology of the tick it plays an important role.

Freezing point determinations were made on several scores of ticks collected in different parts of British Columbia. The unengorged ticks were of both sexes, mostly collected on drags. As no significant differences were observed in the freezing points of males and females, the results quoted are for unengorged ticks of both sexes.

The technique used in determining the freezing points was the thermocouple method of Robinson (1928). Although, as shown by Salt (1936) this method is not absolutely accurate, the error is constant and small and the results are considered to be sufficiently valid to present a reasonably correct picture. It may at this point be mentioned that freezing is lethal to *Dermacentor andersoni* Stiles as none of the ticks recovered even although they were withdrawn from the cold chamber before the undercooling point had been reached.

There was a considerable difference in the freezing points of *Dermacentor andersoni* Stiles from different localities. From one region with a colder climate and longer winters, ticks showed an apparent greater resistance to freezing than did those from districts with less severe or less protracted winters. Ten ticks from Bull River, B. C., collected in April, in a locality where the snow normally lies until well into the middle of June had an average freezing point of −22.7° C. Twenty-three ticks from Kelowna collected during the same month had a freezing point of −13.6° C. Other figures were:

Salmo, B. C.	average of 10 ticks	−11.9° C.
Midway, B. C.	average of 10 ticks	−13.5° C.
St. Mary's Lake, B. C.	average of 10 ticks	−11.6° C.
Creston, B. C.	average of 8 ticks	−11.6° C.
Sheep Creek, B. C.	average of 5 ticks	−12.3° C.
Milk River, Alta.	average of 9 ticks	−13.7° C.

On the basis of the above determinations, it would appear that ticks, with the exception of those that overwinter under very rigid conditions of climate have a freezing point between −10° C. and −14° C.

Ticks in all stages of engorgement appear to be less resistant to freezing than unfed ticks as the following determinations show:

[1] Contribution No. 2156, Division of Entomology, Science Service Department of Agriculture, Ottawa, Canada.

Average freezing points of six fully eng. *D. andersoni*	−5.8° C.
Average freezing points of two three-fourths eng. *D. andersoni*	−5.4° C.
Average freezing points of four one-half eng. *D. andersoni*	−7.1° C.
Average freezing points of seven one-third eng. *D. andersoni*	−6.3° C.
Average freezing points of four one-fourth eng. *D. andersoni*	−7.2' C.

There may be considerable economic significance in this high freezing point of engorged ticks. If an occasional unusually early spring should bring ticks out of hibernation, and they succeed in engorging on cattle or sheep and drop off replete, one cold night with temperatures below −7° C. (19.4° F.) would kill a great many.

No figures are available on nymphal ticks, but as ticks hibernate both as nymphs and adults, presumably nymphs are as resistant as the adults. Engorged nymphs frequently are found in mid-July and such nymphs would normally enter hibernation and emerge as adults in the spring. However, as engorged nymphs would presumably exhibit as little resistance to freezing as engorged adults, it is concluded that any engorged nymphs caught by the onset of winter must have completed their metamorphosis if they are to survive until spring. Engorged nymphs dropped late in the autumn presumably would perish.

Where does *Dermacentor andersoni* hibernate? This tick rarely has been recovered from hibernation quarters in nature, but many of them undoubtedly crawl under dead leaves and other litter and probably beneath flat rocks and similar hiding places. Many also overwinter in rodent burrows. In any of these situations, given a snowfall of more than two inches, the hibernating ticks should be well protected against temperatures down to −17.8° C. (Zero F.) or lower as was demonstrated by Mail (1932). An attempt to verify this statement was made at Kelowna, B. C. Three sets of thermocouples were buried in a heavily infested field in October. The first set was buried in the ground by bushes where ticks were common, the thermocouples being placed at 3, 6, 12 and 18 inches deep. The second and third sets of thermocouples were inserted in rodent burrows 12, 18, 24 and 36 inches down the burrow in one instance and 6, 12, 24 and 36 inches in the other. In December, with about 3 inches of snow on the ground, the first temperature readings were taken. The lowest temperature of any thermocouple was 0° C.

In January temperatures were again taken and the lowest temperature of any couple was −3.0° C. with an air temperature of −4.5° C. and at the February reading the least protected thermocouple registered −1° C. Unfortunately this winter has been too mild really to test the ability of hibernating ticks to survive and a more accessible and permanent temperature recording installation with "planted" ticks is planned for next season.

Oddly enough engorged seeds of *Dermacentor andersoni* dropped from a rabbit on July 26 and on which freezing point determinations were run ten days later showed a remarkable resistance to freezing. The freezing points of five batches of seeds were −22.5, −22.5, −22.5, −24 and −23° C.

Eggs of *Dermacentor andersoni* exhibited similar resistance, three batches freezing at −28°, −27° and −26° C. Macerated eggs froze at −8° C. As seeds and eggs normally are present in nature only during the spring and early summer, there appears to be no point in this protective resistance unless it is a provision of nature to enable eggs to escape late frosts.

FREEZING POINTS OF OTHER TICKS.—Nine unfed *Ixodes californicus* Banks showed an average freezing point of −12.5° C. and four engorged ticks of the same species froze at −7.7° C. Thus it would appear that *I. californicus* from the British Columbia coast have freezing points within the same range as *Dermacentor andersoni* from the interior. Apparently then, *I. californicus* are relatively hardy where temperature alone is considered, and the limiting factor is probably moisture, which would preclude their becoming established in the interior. Were they ever established at Revelstoke, B. C. in the interior, where the vegetation is of the coast type and precipitation is high, *I. californicus* would probably survive.

The mink tick, *Ixodes texanus* Banks, is the tick most resistant to adverse conditions of any of the strains maintained at the Kamloops laboratory. It can withstand long periods of desiccation and long fasts, and it likewise possesses a high resistance to cold. The average of

freezing points for six *Ixodes texanus* was −23.2° C.

Ixodes californicus Banks and *Ixodes texanus* Banks in the engorged state both register similar high freezing points, close to engorged *D. andersoni*.

Average freezing point of four engorged *I. californicus* Banks	−7.7° C.
Average freezing point of eight engorged *I. texanus* Banks	−7.0° C.
Average freezing point of twenty-two engorged *D. andersoni* Stiles	−7.4° C.

An engorged tick of another species, however, registered a consistently lower freezing point and this is probably correlated with the known facts of its hibernation habits. This tick, *Haemaphysalis cinnabarina* Koch according to Gregson (1942) normally engorges on birds in the autumn and has a long preoviposition period, the eggs appearing in the spring. It thus hibernates as an engorged adult and if it possesses as little resistance to freezing as do engorged *Dermacentor andersoni*, *Ixodes californicus* and *I. texanus*, it might suffer a high mortality in a severe winter. Freezing point determinations on six engorged *H. cinnabarina* averaged −11.3° C., which gives this tick a decided advantage in cold weather over the other species mentioned.

LETHAL HIGH TEMPERATURES FOR *Dermacentor andersoni*.—By using a thermostatically controlled water bath, some observations were made on resistance of *D. andersoni* Stiles to high temperatures. In most cases the ticks were exposed to the stated temperature for a period of five hours before being removed and a final observation made twenty-four hours later.

43.5° C.	Ten ticks exposed to this temperature for 24 hours showed no ill effects.
45° C.	Ten ticks exposed to this temperature for five hours. On removal most of the ticks were comatose. Eighteen hours later nine had entirely recovered and one was inactive. Seventy-two hours later all the ticks had completely recovered.
46.5° C.	Twenty-four hours after exposure to this temperature for 5 hours, only one of the 10 ticks was alive.

Apparently the lethal high temperature for unfed *D. andersoni* is between 45° and 46.5° C. after a five-hour exposure. Ticks in British Columbia would rarely, if ever, be exposed to such temperatures in nature.

SUMMARY.—*Dermacentor andersoni* Stiles is present in large numbers in southwestern Saskatchewan, southern Alberta and southern British Columbia east of the Coast Range.

Unfed ticks have an average freezing point of between −10° C. and −14° C. except where exposed to unusually severe or protracted winters where they appear to develop a greater resistance to freezing.

Engorged ticks of several species have high freezing points, between −5° C. and −7° C. An exception is found in the bird tick, *Haemaphysalis cinnabarina* Koch, which normally overwinters in an engorged state. The average freezing point of five engorged *H. cinnabarina* was −11.3° C., so this tick exhibits a greater resistance to freezing than engorged ticks of most species.

Eggs of *Dermacentor andersoni* freeze at −28° C. and seed ticks of the same species at about −23° C. Macerated eggs freeze at −8° C.

Unfed *Ixodes californicus* Banks freeze at −12.5° C. and unengorged *I. texanus* Banks freeze about −23° C. When engorged these two species freeze near −7° C.

Most ticks in nature hibernate under debris or in animal burrows where they normally are adequately protected from freezing point temperatures of ticks in Canada.

The lethal high temperature for unfed *Dermacentor andersoni* is between 45° C. and 46.5° C.—3-25-42.

LITERATURE CITED

Gregson, J. D., 1942. Notes on the laboratory rearing of some Canadian ticks. Proc. Ent. Soc. B. C. **39**. (In Press.)

Mail, G. A., 1932. Winter temperature gradients as a factor in insect survival. JOUR. ECON. ENT. **25**: 1049–53.

Robinson, Wm. 1928. Determination of the natural undercooling and freezing points of insects. Jour. Agr. Res. **37**: 749–55.

Salt, R. W., 1936. Studies on the freezing process in insects. Tech. Bul. **116**. Minn. Agric. Expt. Sta.

Time of Planting Susceptible Beans in Relation to Curly Top Injury in South-Central Idaho

A. O. Larson[1] and H. C. Hallock, *U. S. Department of Agriculture,*[2]
Bureau of Entomology and Plant Quarantine

In some years the curly top disease, transmitted by the beet leafhopper, *Eutettix tenellus* (Bak.), causes a heavy loss to the bean crop (Fig. 1) of south-central Idaho. The ravages of this disease thin out the plants in the field to such an extent that only a part of the stand remains. Among the farmers this injury is commonly referred as the "bean blight," and it is frequently attributed to weather conditions, such as a few hot days soon after the beans come up, windy weather, or deficient moisture in the soil. The appearance of the "blight," or curly top, is first noted when the tips of the first trifoliate leaves just starting to appear begin to dry. These small leaves usually fall off, leaving only the first leaves, which appear to be suffering from drought or excessive heat (Fig. 2). The infected young bean plant soon dies. Bean plants that are older when infected by the beet leafhopper, or plants that have not been severely injured by the curly top virus, may develop curled leaves, which later fall off before the plants die (Fig. 3). Bean plants affected in this manner do not produce a crop.

Fig. 1.—Field of garden beans destroyed in 1935 by curly top disease.

Fig. 2.—Bean plant showing first symptoms of curly top disease.

An early description of the effects of the curly top disease on beans was given by Carsner (1926) and additional information in regard to its effects upon the plant was given by Murphy (1940).

Among the bean growers in the Twin Falls, Idaho, area two ideas seem to be prevalent as to the time beans should be planted. One is that it is unsafe to plant before the first of June because of killing

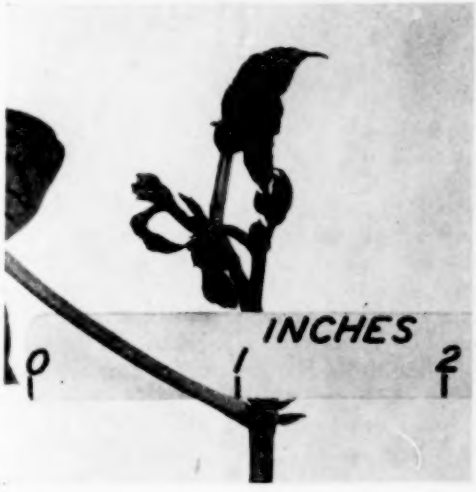

Fig. 3.—Bean plant showing later symptoms of curly top disease.

[1] Retired June 1, 1939.

[2] The investigations reported upon in this article were performed in general cooperation with the Bureau of Plant Industry of the U. S. Department of Agriculture, the Idaho Agricultural Experiment Station, and the State of Idaho Leafhopper Control Administration.

Table 1.—Relationship between planting date, the percentage of plants having curly top, and yield of dried beans.

Date Planted	Curly Top Infection and Yield of Dry Beans per Plot											
	Twin Falls										Filer	
	1936		1937		1938				1939		1938	
					West field		East field					
	Infection	Yield	Infection	Yield	Infection	Yield	Infection	Yield	Infection	Yield	Infection	Yield
	Per cent	*Lbs.*	*Per cent*	*Lbs.*	*Per cent*	*Lbs.*	*Per cent*	*Lbs.*	*Per cent*	*Lbs.*	*Per cent*	*Lbs.*
May 8–11	0.4	87.0	14.7	36.0	0.4	56.5	1.0	43.0	22.1	2.3	9.3	30.3
May 11–13			18.1	37.5	0.5	47.7	0.8	44.0	11.2	4.1	9.3	33.0
May 15–18	0.9	101.0	25.8	37.5	0.7	59.0	1.0	40.3	8.4	12.0	17.3	27.8
May 19–20			33.4	32.5					7.0	9.1	13.6	27.3
May 23–25	2.0	107.0	36.7	34.5	2.6	56.1	4.6	33.3	7.4	9.5	30.6	22.3
May 26–27			49.3	23.5	2.8	58.3	6.9	28.2	8.2	5.3	40.6	18.3
May 29–30					3.5	61.8	6.6	41.9	7.6	6.1	52.3	8.3
June 1–3	5.9	86.0	61.3	19.0	7.4	49.0	14.5	32.7	7.4	8.0	54.9	6.4
June 5–7			61.1	25.0	9.6	50.0	18.3	15.3	12.5	5.9	75.2	3.4
June 8–11[1]	7.3	74.0	50.3	35.0	10.9	43.5	20.0	11.0	12.3	2.0	65.2	5.6
June 12–15[1]	12.1	20.0	44.4	37.0	13.0	35.0	13.6	18.3	13.4	2.2	46.7	14.5
June 16–19			62.0		17.7	19.8	13.9	21.0	15.7	1.3	20.6	57.5
June 20–22	14.2		46.9		10.3	21.8	11.8	13.0	13.0	1.3		
June 24–26			39.3						14.2	1.1		
June 28–29	16.9		32.4						19.3	0.9		

[1] The numbers of bean plants occurring in the plots planted on June 10 and 14, 1937, exceeded those in the other plantings by approximately 1,000 plants as a result of differences in the planter opening, so the high percentage of plants killed by curly top gave no apparent reduction in yield in these two plantings.

spring frosts. However, the weather records of the Twin Falls area show that usually there are no killing frosts after May 18. The other is that susceptible varieties of beans should not be planted before the spring movement of the beet leafhopper from the wild-land areas to the cultivated areas has begun. The theory is that the bean plants will not be up above the soil surface until the movement is over and the young plants will not be exposed to the insects. Observations, however, indicated that early-planted beans were injured less by curly top than later ones.

In order to obtain more information on the best time to plant susceptible beans so as to minimize injury from curly top, plantings of beans were made in Idaho at intervals throughout the season for four seasons near Twin Falls, for three seasons at Buhl, and for one season at Filer. The variety "Bountiful" was used in all these plantings, since it was known to be highly susceptible to injury from the curly top disease, and the results are thought to be representative of the different varieties of garden beans grown under contract. Records for each plot were made on the date of germination, the number of plants, the date that infestation by the beet leafhopper was first noted, the date curly top was first observed on the plants, the total number of diseased plants, and the yield of dried beans. The plots were examined at weekly intervals, and curly top plants were counted and removed. The percentage of the bean plants developing curly top during each season is given in table 1.

BEAN PLANTINGS MADE IN 1936.—During the spring of 1936, 8 plantings of beans at weekly intervals (Table 1) were made at Twin Falls during the period from May 11 to June 29, inclusive. Each planting consisted of a single plot of 8 rows, 22 inches apart and 178 feet long. The plots were planted consecutively, each of them from the second to the eighth being located adjacent to the last planted plot, and they were all given the same cultural treatment. Although the beans were planted with the same planter, the spacing of the seeds in the rows was not the same in all plots.

Although beet leafhoppers were not numerous in 1936, the differences in curly top were sufficiently great in the different plantings to be significant. Repeated examinations showed that there were practically no infected bean plants in the earliest planted plots, there being only 16 infected plants out of 3,574, or 0.4 per cent. The number and per cent of infected plants increased in each succeeding plot. Although the percentage of infected plants in 1936 was small when compared with that of 1937 and the reports of some other years, it is interesting to note the increase in the percentage of infected plants in the later planted plots as compared with the earliest planted plots (Table 1).

There was a gradual increase of infected plants in the plots, from 0.4 per cent (planted May 11) to 16.9 per cent (planted June 29), but the first three plantings (May 11, 18, and 25) were only lightly infected.

It was impossible to obtain complete data on the yield of all the eight plots because an unseasonably heavy frost on the morning of September 15 killed the plants in plots 6, 7, and 8. Plot 6 was harvested, however, and the threshed beans were hand sorted, but the other two plots were too immature to harvest. The data presented in table 1 show a gradual increase in yield from the first to the third planting (May 25), then a gradual decrease.

BEAN PLANTINGS MADE IN 1937.—In 1937 the beans were planted at Twin Falls on Mondays and Thursdays during the period from May 10 to June 28 (table 1), comprising a total of 14 plantings. Each planting consisted of a single plot of 4 rows, 22 inches apart and 198 feet long. The procedure in arranging plots and in recording data was the same as for the 1936 series. The first diseased bean plants were noted on June 21, when 15 plants infected with curly top were found scattered through the three earliest planted plots, which constituted an average of one and one-fourth diseased plants per row. By June 30 the number of diseased plants had increased to 5 per row in the first planting and 46 per row in the plot planted June 3. Throughout the season the earlier planted plots continued to have fewer diseased plants than did the later planted plots. The highest percentage of infected bean plants was found in the plot planted on June 17. The first three plots, which had germinated before the movement of the beet leafhoppers began, yielded not only the most pounds per plot, except the plot planted June 14, but a greater quantity of beans per plant than any of the plots planted later. The high average yield per plant was 0.34 ounce on the plot planted May 13. This average dropped to 0.18 ounce per plant on the plot planted June 3 and remained at 0.21 ounce for the plots planted June 10 and 14. Yield records could not be obtained for the last four planting dates (June 17, 21, 24, and 28) because a heavy frost on the morning of September 24 killed the bean plants. Table 1 gives complete yield records for the 10 plots planted May 10 to June 14.

Seven plantings of beans were made at weekly intervals on a farm about 5 miles west of Buhl during the period from May 14 to June 25. Each planting consisted of a single plot of four rows, and the total area of the seven plots comprised a little more than one-half acre. They were located adjacent to beets which had been used for spray tests and in a locality where the beet leafhoppers were very abundant. Examinations disclosed as many as 98 leafhoppers on one beet, and the population was consistently high on the beans.

Curly top was first observed in the earliest planted beans on June 14, one month after planting, when 21 plants were found to be infected. It then continued to develop for a period of 5 weeks until all the beans were destroyed. In the later plantings the disease developed sooner following seeding than in the early plantings and killed the beans more quickly. In the planting made June 18 the plants were badly diseased by July 12 and were all diseased by July 16. No marketable beans were produced in the plots at Buhl.

BEAN PLANTINGS MADE IN 1938.—In 1938 the beans were planted in two fields at Twin Falls, one field at Filer (Table 1), and one field at Buhl. As the two fields at Twin Falls were adjoining, the Twin Falls planting was replicated. The plantings in each of the fields at Twin Falls, known as the west and east fields, respectively, were made each Monday and Thursday during the period from May 9 to June 20) except on May 19 when the ground was too wet to plant) and comprised a total of 12 plantings. At Filer the 12 plantings were made on Mondays and Thursdays during the period from May 9 to June 16 while at Buhl the 18 plantings were made each Monday and Thursday during the period from May 9 to July 7.

In the Twin Falls west field each planting consisted of a single plot of four rows averaging approximately 600 plants per row. Only 0.4 per cent of the bean plants in the earliest planting developed curly top. The percentage of diseased plants increased in each succeeding planting to 17.7 per cent in the next to the latest planting on June 16. The first three plantings showed less than 1 per cent of curly top-infected plants, but all later plantings exceeded that figure.

The results in the Twin Falls east field

were similar to those in the west field in that the earliest plantings had the least curly top. In this field each planting consisted of a single plot of the same size as has been described for the west field. Here about 1 per cent of the plants in the first three plantings exhibited curly top, while the maximum of 20 per cent of diseased plants occurred in the planting of June 9. The results obtained from these two fields are shown in table 1 and agree with those obtained during 1936 and 1937, when in each case the earlier planted beans had less curly top than the later plantings.

Each planting at Filer consisted of a single plot of four rows averaging approximately 520 plants per row. Here, also, the earlier plantings had less curly top. The proportion of plants having curly top ranged from 9.3 per cent in the first and second plantings to 75.2 per cent in the ninth planting, which was made on June 6 (Table 1). In the last planting 20.6 per cent of the plants were infected.

The plantings at Buhl were made in the same manner, and each plot was of approximately the same size as in the Twin Falls and Filer series. The plantings at Buhl were extended to July 7, much later than in any other series, in order to determine whether the beet leafhopper would continue to infect beans with curly top virus and cause injury to the young bean plants during the summer. The field where these beans were planted was in a district usually experiencing the heaviest beet leafhopper infestation in south-central Idaho, and, consequently, the bean plants were exposed to severe infection by curly top. As a result, the percentage of the bean plants having curly top ranged from 70.9 to 99.1 per plot. No marketable beans were produced in any of the plots. In general, the later planted beans suffered a greater degree of injury than the earlier planted ones, and they also developed the disease in less time after planting than those in the earlier planted plots.

BEAN PLANTINGS MADE IN 1939.—In 1939 the bean plantings at Twin Falls and Buhl were made each Monday and Thursday from May 8 to June 29. The procedure in arranging the plots and in recording the data was the same as during 1938, so the plantings at Twin Falls and Buhl were replicated. The results of the tests of 1939 had less value than the earlier tests, as a heavy infection of common bean mosaic occurred in the plants. A smaller percentage of the beans planted from May 15 to June 1 at Twin Falls had curly top than those planted earlier or later.

RELATION OF INFESTATION AND MIGRATION AND MIGRATION TO THE CURLY TOP.—The intensity of the infestation of the beet leafhopper as well as the time of its movement into the cultivated area appears to govern to some extent the amount of curly top resulting in beans. Surveys to determine the extent of curly top in commercially grown beans were made in the principal bean-growing districts of south-central Idaho during eight seasons. Records were made each season in from 40 to 100 fields scattered over a wide tract on both sides of the Snake River. Counts of the diseased plants in 100 consecutive bean plants in a row were made in four different parts of each field, and the average of the four counts was called the average for the field. The results of these surveys, given in table 2, showed

Table 2.—Relationship in south-central Idaho between relative intensity of infestation by the beet leafhopper on sugar beets and the percentage of curly top in beans in early July.

Year	Relative Intensity of Beet Leafhopper Infestation on Sugar Beets	Range in Percentage of Plants Having Curly Top	
		Garden bean varieties	Great Northern beans
		Per cent	*Per cent*
1930[1]	Heavy	—	0–96
1935	Heavy	—	1–68
1936	Low	3–5	—
1937	Heavy	0–99	1–53
1938	Light medium	0–13.5	0–5.5
1939	Low	0–3	0–1
1940	Medium	1.8–44	0.3–8.5
1941	Medium heavy	1.0–59.75	0–58.25

[1] Annand *et al.* (1932).

that during the years 1930, 1935, and 1937, when there were heavy infestations of the beet leafhopper in the cultivated areas, the beans were severely damaged by curly top. On the other hand, during the years 1936, 1938, and 1939, when the leafhopper infestations were light, the beans showed little curly top. In all eight seasons there was a gradual decrease in the amount of disease from the Castleford-Buhl-Wendell districts on the west to the Murtaugh-Hazelton districts on the east. Experience has shown that the western

districts generally receive a heavier influx of beet leafhoppers during the spring movement than the eastern districts.

By comparing the dates of leafhopper movement shown in table 3 with the results given in table 1 it will be seen that in every instance when planting was done after the beginning of the movement of the beet leafhopper from its spring-breeding areas to the cultivated areas, the beans had more curly top than those planted just before the movement began. Since curly top infection in young beans is more destructive than in older beans and since beans appear above the ground 8 to 12 days after seeding, those planted after the beginning of a spring movement of the leafhopper will be seedlings during the peak of the leafhopper movement, inasmuch as the leafhopper distribution usually extends over a period of several weeks and usually reaches a peak from 2 to 3 weeks after the start. A further comparison of the data in tables 1 and 3 shows that the last planting dates for beans having light curly top injury and no reduction in yield were May 25, May 17, May 30, and June 1 at Twin Falls in 1936, 1937, 1938, and 1939, respectively; and May 19 at Filer in 1938. They also indicate that for best results garden varieties of beans should generally be planted just before the start of the spring influx of the beet leafhopper. During a period of 13 years the average date of the beginning of the spring migration in the Twin Falls district has been about May 27. Three recent exceptions were April 28 in 1934 and June 13 in 1927 and 1932. The spring migration in 1934 was practically complete before the beans were up, which resulted in a fair bean year in spite of the extremely heavy leafhopper population.

Table 3.—Relation between spring movement of the beet leafhopper into cultivated districts and injury to beans.

Year	Start of Movement of Spring Generation into Cultivated Area	Date of Peak of Spring Generation Movement into Cultivated Area	Last Planting Date for Low Curly Top Injury and When No Decreased Yield Occurred	
			Twin Falls	Filer
1936	May 25	June 22	May 25	—
1937	June 3	June 23	May 17	—
1938	May 30	June 17	May 30	May 19
1939	May 17	June 14	June 1	—

Practically the same results were obtained at Twin Falls and at Filer, but at Buhl, where the bean plants were exposed to intense infestation by the beet leafhopper, the resultant curly top infection led to a complete loss of the crop regardless of the time of planting, except in 1939, when a partial crop was obtained. The beet leafhopper population in 1939 was very low, however. Commercial plantings of the garden bean varieties were also raised in 1939 at Clover and Castleford in the west end of the district.

CONCLUSIONS.—Garden bean varieties planted just before or at about the start of the spring migration of the beet leafhopper in the Twin Falls district of Idaho and in the district immediately east of Twin Falls should nearly always escape severe injury from curly top disease.

The planting of garden varieties, susceptible Great Northern, or Pinto beans at any time in the west districts, such as beyond Flier and around Buhl, Castleford, and Clover, is attended by a very high degree of risk, but some chance of reducing losses from damage by curly top is afforded by early planting.—3-27-42.

LITERATURE CITED

Annand, P. N., J. C. Chamberlin, C. F. Henderson and H. A. Waters. 1932. Movements of the beet leafhopper in 1930 in Southern Idaho. U. S. Dept. Agr. Circ. **244.**

Carsner, E. 1926. Susceptibility of the Bean to the Virus of Sugarbeet Curly Top. Jour. Agr. Res. **33**:345–8.

Murphy, D. M. 1940. Bean Improvement and Bean Diseases in Idaho. Idaho Agr. Expt. Sta. Bul. **238.**

Tenth Annual Convention of National Pest Control Association

Hotel William Penn, Pittsburgh, Pennsylvania

October 26, 27, and 28, 1942

Entomologists Always Welcomed

Biological Notes on the Basswood Leaf-miner, *Baliosus ruber* (Weber)[1]

A. C. Hodson, *University of Minnesota, St. Paul*

The basswood, *Tilia americana*, is attacked throughout its range by a reddish, wedge-shaped beetle, the basswood leaf-miner, *Baliosus ruber* (Web.). Infested leaves are injured by the surface skeletonizing of adults and mines formed by the larvae. Occasionally the injury may be so conspicuous that stands of basswood present a fall aspect in early August. Trees in such a condition have been a common sight in the Lake Park Region of Minnesota where there has been an outbreak in existence nearly continuously since 1935. Repeated attacks by the basswood leaf-miner have weakened many trees to such a degree that their crowns appear thin and are easily recognized by the number of dead branches. However, in spite of the generally unthrifty character of the damaged trees, very few have died even in localities where the feeding has been most heavy.

Baliosus ruber has been recognized as a pest of basswood, oaks and apple for many years, for it was Harris (1835) who first mentioned the damage. He found the beetles feeding on apple and oaks as early as 1827. Packard (1890) has quoted correspondence from W. L. Devereaux of Clyde, New York, who reported the destruction of the entire foliage of every basswood in many forests with the exception of that in very tall trees. Beutenmuller (1890) also mentioned the mining of the leaves of apple and linden. Chittenden (1893, 1902) suggested that basswood was probably the preferred host and he presented brief notes on the habits of the insect. From Canada, Caesar (1912) reported heavy damage near Rideau lakes in a summary of forest insect depredations in Ontario. Houser (1918) likewise has referred to the beetle as an important enemy of linden and apple. In the same year Nicolay & Weiss (1918) gave a detailed description of the larval and pupal stages and also some notes on life history. They found one generation in New Jersey with pupation taking place during the last week in July and the first week in August. According to their observations larval mines were most common in oaks and the larvae were easily visible during July. In a more recent contribution Brown (1940) has stated that *B. ruber* has been increasing yearly at La Trappe, Quebec.

When it was recognized that the basswood leaf-miner deserved consideration as an economic insect, life history studies were undertaken. The observations reported in this paper were made in the vicinity of the Forestry and Biological Station located at Itasca State Park, in northern Minnesota. Some supporting material was gathered in the hardwood area lying southwest of Itasca Park. Infested trees were sampled at regular intervals and caged beetles were kept under observation to obtain data on egg-laying, feeding habits, and adult longevity. Copulating pairs of beetles were confined on basswood trees with sleeve, wire cloth cages.

Basswood leaf-miner adults were found in hibernation under leaves and trash beneath the host trees. They became active in the middle of May, about the time when basswood leaves begin to unfold. They fed sparingly during the warmest hours of the day at this time, but their activity increased as the season progressed. By the first of June the skeletonizing was becoming conspicuous and the first pairs were seen in copula. At the end of the second week in June nearly all beetles in the field were mating. The first eggs were observed on June 15.

Eighteen pairs of copulating beetles were confined on basswood leaves in individual cages on June 27, 1940. Thereafter the cages were examined daily and shifted to new leaves each week. Caged beetles started ovipositing July 7 and continued to deposit eggs until August 1. Egg-laying proceeded at a fairly regular rate until the last week in July when the number of eggs was much smaller. There was an average of 37.1 eggs per female with a range of from 34 to 43. With the exception of one male all the beetles were alive on August 7 when the experiment was closed, but no eggs were deposited after August 1. Feed-

[1] Paper No. 1967 Scientific Journal Series, Minnesota Agricultural Experiment Station, St. Paul.

ing and copulating continued throughout the study, with some feeding being observed after all copulating and oviposition had ceased. Samples taken from other trees indicated that the beetle population began to thin out about the middle of July, although scattered mating pairs were seen as late as July 28.

Eggs were deposited singly at the edge of an area skeletonized by the female. The egg is forced part way into the epidermis of the upper leaf surface, with the rough edges of the torn epidermis elevated along the sides as shown in figure 1. After an egg was deposited the female covered it with feces so that it appeared as a brownish, elliptical, patch of excrement. The average size of the eggs was 1.06 by 0.58 mm. A closely related species, the locust leaf-miner, *Chalepus dorsalis* Thunb., deposits its eggs in groups of several with the eggs overlapping one another, but this method was never observed for the basswood leaf-miner; instead single eggs were deposited. However, those deposited by one female often would be found lying closely parallel to each other in numbers up to four.

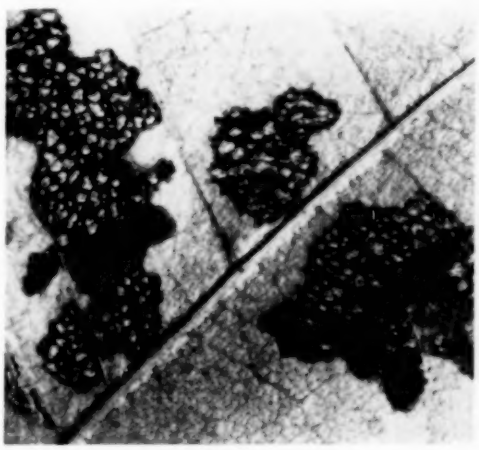

FIG. 1.—The eggs of *Baliosus ruber;* photographed from sample preserved in alcohol.

The study of eggs which had been laid by caged females was terminated early by an unexpected natural circumstance. When these eggs did not hatch in a reasonable length of time they were examined and found to be parasitized. Because of this event an exact figure on the incubation period was not obtained. Fortunately, regular sampling of other infested trees provided information which indicated that embryonic development was completed in about ten days. Larvae left the egg from the end which was imbedded in the leaf tissue and proceeded to feed without ever being exposed on the surface. At first the feeding was confined to small individual mines, but in the later stadia as many as three larvae were found frequently in one common mine. Harris (1835) described the mines and stated that they occupied an area of about one square inch. In this study the areas of several hundred mines were measured and the average was $1.02 \pm .007$ square inches. A typical larval mine is illustrated in figure 2.

FIG. 2.—Basswood leaf showing larval mine and adult skeletonizing.

Although the progress of larval development could not be followed in the cages, some newly hatched larvae were discovered in a basswood stand about one quarter of a mile distant. These larvae worked in their mines for from four to five weeks where they deposited their excrement at random in the mine instead of leaving a conspicuous trail as is characteristic of some leaf-miners. The peculiar, spiny pupae were observed first in the mines on August 1. At this time only 6.2 per cent of the larvae had pupated. Five days later 43.5 per cent of the individuals collected were pupating and by August 15 leaf samples showed nearly all, or 98.6 per cent, in the pupal stage. The high percentage of pupae on this date indicates that the egg-

laying of the unprotected beetles did not continue for as many weeks as was observed in the cages.

Pupae were found in a great variety of positions in the mines, probably where the larvae had happened to stop when they finished feeding. Pupation required from 8 to 12 days, the time varying with the degree of exposure to direct sunlight. Upon emergence the young adults started feeding immediately and continued to skeletonize the leaves until they were forced to seek hibernation quarters.

Larval mines present the most conspicuous evidence of the presence of *Baliosus ruber;* however, injury caused by adult feeding may also be of considerable importance. This skeletonizing is shown in figures 1 and 2. It is found usually on the upper leaf surface, but may occur on either surface; an observation contrary to that reported by Chittenden (1902) who mentioned that skeletonizing was confined to the lower surface of leaves. When there is a moderate infestation larval mines are always the most important, the skeletonizing causing only slight damage in small scattered areas. At times, however, the beetles may become extremely abundant and cause complete browning as a result of their feeding. A striking example of such a case was seen in the summer of 1941 near Detroit Lakes, Minnesota. Adult skeletonizing was so extensive on some leaves that the entire epidermis was destroyed and as a result no eggs were found on these leaves. This condition was found in over half the trees of an area of considerable size. The infested basswoods were scattered through a mixed stand of hardwoods where oaks were also present. Many of the latter showed evidence of the insect but the damage was light.

When one reflects upon the injury caused by a defoliating insect the question of the relation of population density to degree of damage is often considered. The practical value of a knowledge of this relationship is found, of course, in its application to the prediction of probable damage and need for control. In this study an estimate of the probable number of beetles necessary to cause severe larval damage was calculated. It was found that the average sized basswood leaf had an area of 15.4 ± 1.6 square inches. Inasmuch as the larval mines averaged about 1 square inch, 15 eggs would be required for larvae to mine the entire area of one leaf. Each female was found to have deposited about 37 eggs so we can conclude that about 40 pairs of beetles per 100 leaves would be necessary to cause complete defoliation. The average number of eggs deposited in completely destroyed leaves was not determined but in three areas where the damage was light the number of eggs averaged 6.8, 3.0, and 2.5 per leaf. Such an estimate is subject to modification because of differences in leaf size under different growing conditions and other variables such as the undetermined relation between the amount of leaf surface destroyed by larvae to that skeletonized by the adults. However, a method of this kind would be useful in determining the economic status of a population, and as a result the need for immediate action on control.

Heavy mortality in any stage of development always can affect the results of predictions. At Itasca State Park egg parasitism would have reduced the predicted damage greatly because in four localities in an area of about seven square miles parasites were present in 100, 98.8, 66.6, and 47.5 per cent of the eggs. Several hundred unhatched eggs were dissected to determine the cause of death. These parasites were small Hymenoptera which had pupated in August. They did not emerge during the summer and may have entered a pupal diapause at that time. Samples were placed in cold storage to break dormancy but unfortunately no adults were obtained for identification. In 1941 only an occasional beetle could be found in the first two of the areas for which egg parasitism is listed above. In the fourth and fifth localities there was light damage.

No experiments on chemical control were designed specifically for this species but a chance observation in a stand of basswood which had been sprayed for the control of *Malacosoma disstria* Hbn. gave some promising results. These trees had been sprayed with lead arsenate, 2.5 pounds to 100 gallons, to which one pint of raw linseed oil had been added. Here the trees were entirely free from larval mines and showed only very light adult feeding. In a neighboring unsprayed stand the damage was heavy. The pest should be easy to kill with foliage poisons because of the relatively long period in the spring and fall when the beetles are feeding.—3-6-42.

LITERATURE CITED

Beutenmuller, W. 1890. Food habits of some Chrysomelidae. Ent. Amer. **6:** 175–78.
Brown, A. W. A. 1940. Ann. Rept. Forest Insect Survey 1939, p. 22.
Caesar, L. 1912. Insects of the season in Ontario. 42nd Ann. Rept. Ent. Soc. Ont. 1911, p. 34.
Chittenden, F. H. 1893. Notes on the food habits of some species of Chrysomelidae. Proc. Ent. Soc. Wash. **2:** 261–67.
Chittenden, F. H. 1902. The leaf-mining locust beetle with notes on related species. U. S. D. A. Div. Ent. Bul. **38:** 70–89.
Harris, T. W. 1835. Upon the economy of some American species of Hispa. Boston Jour. Nat. Hist. **1:** 141–51.
Houser, J. S. 1918. Destructive insects affecting Ohio shade and forest trees. Ohio Agri. Expt. Sta. Bul. **332:** 236.
Nicolay, H. S., and H. B. Weiss. 1918. Notes on *Chalepus rubra* Web. Can. Ent. **50:** 398–400.
Packard, A. S. 1890. Insects injurious to forest and shade trees. Fifth Rept. U. S. Ent. Comm. p. 480

Epicallima coloradella (Wals.), an Inhabitant of Perennial Apple Cankers in the Northwest

M. A. YOTHERS, *U. S. Department of Agriculture, Bureau of Entomology and Plant Quarantine*[1]

In the course of a study of the woolly apple aphid, *Eriosoma lanigerum* (Hausm.), in its relation to the perennial apple canker in the Wenatchee, Wash., district it was found that among the numerous insects present one of the most common canker inhabitants was the oecophorid moth *Epicallima coloradella* (Wals.). Numerous observations were made on this insect, since there appeared a possibility that it might play some role in the development or transmission of the disease.

Perennial cankers are permanent lesions in the bark and outer wood of apple and pear trees in certain orchard districts of the Pacific Northwest, caused by the fungus *Neofabraea perennans* (Zeller & Childs) Kienholz (*Gloeosporium perennans* Zeller & Childs). When a few years old the lesions have a very ragged appearance (Fig. 1, *A*, and Fig. 3, *A*). Underneath the ragged bark are concentric woody rings, usually formed about a knot or wound of some kind. These are the annual rings of dead callus and the outer ring of live callus of the previous or current season (Fig. 1, *B*). On this new callus the woolly aphid feeds and propagates and is intimately associated with the disease (Childs 1929, Cooley 1932, McLarty 1933, and Yothers 1932).

Underneath the torn canker covering there is usually a mass of debris, composed of the live and dead bodies, cast skins, and frass of numerous insects of several kinds, often all enmeshed in the tangled webbing of the larva of *Epicallima coloradella* (Fig. 1, *B*).

HISTORY AND DISTRIBUTION OF *Epicallima Coloradella*.—Walsingham (1888) described *Epicallima coloradella* from a single specimen from Colorado given him by Ragonot and placed it in the genus *Oecophora*. Busck (1904) listed it as from Kaslo, British Columbia, and the Moscow Mountains in Idaho. The first

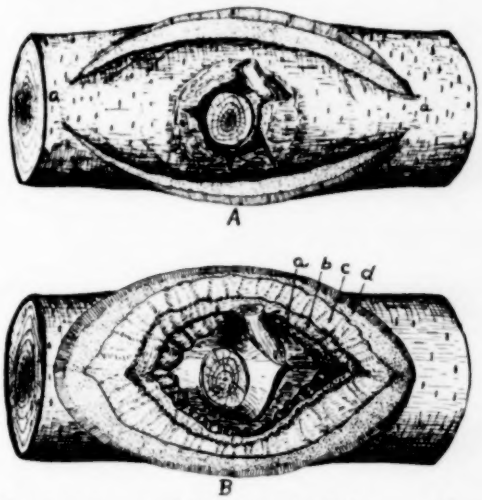

FIG. 1.—*A*, perennial apple canker lesion on section of apple limb, showing the ragged outer bark, attached at either end, *a*, to the live bark, beneath which the larvae of *Epicallima coloradella* live. *B*, the same as *A*, but with the lid of torn bark removed and the debris cleaned out, revealing the inner appearance of the lesion and where the *coloradella* larvae feed on the dead, friable, woolly aphid-galled plant tissue, *a*. One year-old callus is shown at *b*, current season callus at *c* (where woolly aphid feeds), and separation of dead and live bark at *d*. ×⅔.

[1] The writer is indebted to F. W. Carlson for the drawings in figure 2 and to Paul B. Allen, Jr., for assistance in much of this work.

record of the habits of this insect was made by Trumble (1926), who presented some miscellaneous observations and his conclusions as to its life history, habits, and economic importance. Newcomer (unpublished notes) found larvae of various stages plentiful in April and May, 1929 in old apple stumps where no canker was evident, near Peshasin, Wash., about 20 miles northwest of Wenatchee. On May 24 he observed larvae, pupae, and adults. The writer (Yothers 1932) referred to the larvae as inhabiting perennial cankers and spinning their webbing among the mis-

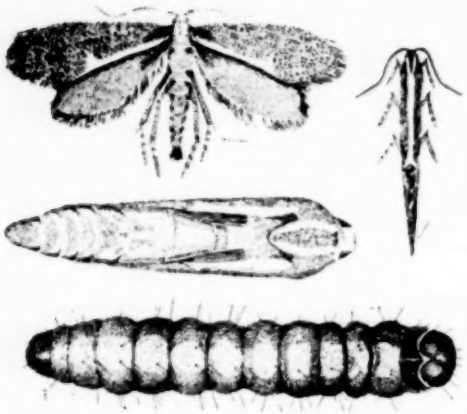

FIG. 2.—*Epicallima coloradella*. A, larva, and B, pupa (×10); C, female moth with wings folded over body, D, with wings spread (×5).

cellaneous debris filling these lesions. There seems to be no other reference in the literature on the habits of this species. Treherne (1921) discussed *E. dimidiella* (Wals.), a closely related species, as occurring in British Columbia as a refuse feeder in cracks and crevices of the bark of fruit trees. Essig (1926, p. 719) referred to *E. dimidiella* as "the brown apple moth." Larvae of what seems to be *E. coloradella* have been taken by the writer in perennial canker lesions in orchards at Dayton, Pullman, Spokane, Waitsburg, Wenatchee, and Walla Walla, Wash., and near Lewiston, Idaho. In all these districts larvae had been working in most of the canker lesions, especially the older ones, at some time or other in their existence. In the Wenatchee district the insect is generally distributed, but is found most abundantly in orchards in the wooded, foothill sections nearest to the mountains.

Specimens of this species from several localities in Washington collected by J. F. Gates Clark are in the United States National Museum. Among them is a male from Pullman (24-VI-33, J. F. Gates Clark) reared from the terminal leaves and buds of *Crataegus brevispinus*. One other specimen (a female) from Clarkston (1-VII-33, J. W. Bales), was reared from the terminal leaves of apricots.

NOTES ON LIFE HISTORY AND HABITS.—The egg of this species is not known to the writer. Trumble states that eggs are laid in cracks in the bark of the tree. Presumably most of them are deposited in or near the cankers.

The larva (Fig. 2, *A*) is slender, from 9 to 12 mm. in length and 1.6 mm. in diameter when full grown. Larvae are pink to brown in color, almost white when young, but become darker with age. They are exceedingly active, being able to crawl away with great rapidity, or to squirm and throw themselves violently about when disturbed. The larvae feed, for the most part at least, on the dead and decaying wood and bark, particularly on the old, aphid- and frost-killed and desiccated callus tissue (Fig. 1, *B*). These dead, friable tissues are often found riddled by the burrows of this larva. It does not confine its movements, however, to these definite localities within the lesion, but crawls around throughout the inside of the canker, leaving its excrement and other debris entangled and sewn together in its webbing. The larvae do not feed on the live, growing callus, except such as they sometimes scrap from the junction of live callus and old bark or wood. Apprently the larvae prefer lesions or other wounds with more than the average amount of moisture in them, since more were found under these conditions than in extremely dry cankers. The larvae may be found in any suitable canker or wound in any part of the tree, but since most of the suitable cankers are on the trunk or scaffold limbs, most of the larvae are found in that area.

The pupa (Fig. 2, *B*) is about 6.5 mm. in length and 1.75 mm. in diameter and is light brown. Pupae are sometimes found in exceedingly flimsy cocoons, but whether cocoons are always present is difficult to say, since they are so meager.

The adult (Fig. 2, *C* and *D*) is very slender when at rest, its wings forming an extremely narrow ridge over the body. In

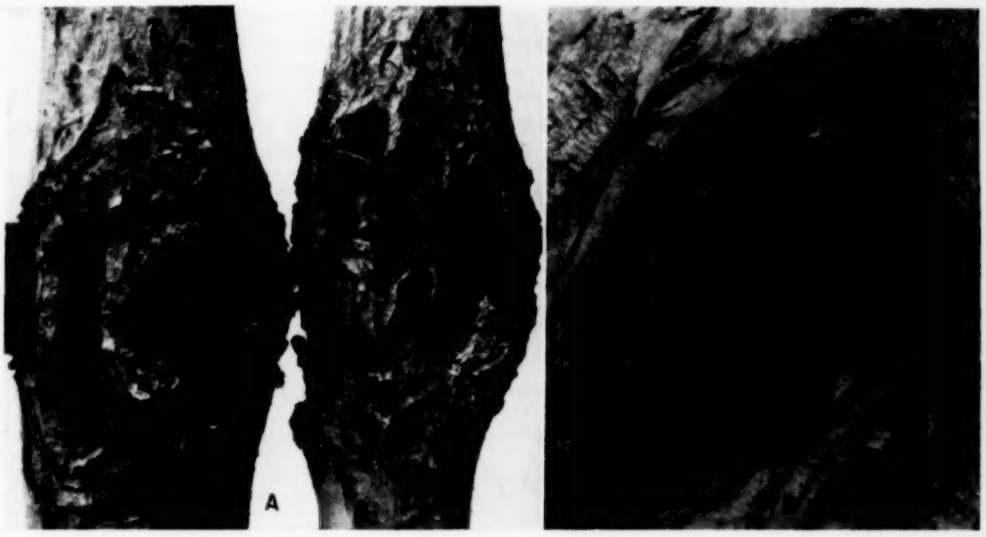

FIG. 3.—*A*, external appearance of the perennial apple canker, *Gloeosporium perennans* Zeller and Childs. on apple limb, Wenatchee, Wash. These cankers are several years old, and lesions of this type are often inhabited by the larvae of the Oecophorid *Epicallima coloradella*. ×5/7.
B, perennial canker lesion on scaffold limb of apple tree, with the outer ragged bark removed to show the mass of woolly aphid and other debris enmeshed with the webbing of the larva of *E. coloradella*.

this position there is formed on the thorax and forewings a characteristic light-yellow figure, as shown in figure 2, *C*. When the wings are spread out this figure takes on a different shape (Fig. 2, *D*). At rest the moth is about 9 mm. long and with wings outspread it measures about 15 mm. from tip to tip of wings.

The moths have been observed sitting on the bark of apple tree trunks and scaffold limbs. They are not strong fliers, and when disturbed fly up rather suddenly, but only for a few inches or feet.

SEASONAL HISTORY.—Larvae in all stages from 2 to 12 mm. in length have been found throughout the year, pupae have been taken from April 15 to June 25, and adults have been seen from May 1 to June 24. Apparently *Epicallima coloradella* has no true hibernating period, since larvae in various stages have been found active throughout the year within canker lesions. Because of this fact it has been difficult to surmise the number and time of molts, the length of instars, or the number of generations. Since moths have been observed only in May and June, there is probably only one generation a year.

ABUNDANCE.—A study of the incidence of the insect in cankers in one experimental orchard in the Cashmere, Wash., district, about 13 miles northwest of Wenatchee, in the timbered foothills area, showed that 12 per cent of the 2992 canker lesions were inhabited by these larvae. This included hundreds of young cankers less than 2 or 3 years old, in which there was little or no suitable decayed, woody material for the larvae to work in. The infested cankers contained an average of 3 larvae each, and the highest number found was 28. Cankers in other orchards farther removed from the timbered areas did not show so many of the larvae.

HOSTS.—A search for the insect's native host failed to reveal its presence in any trees other than apple.

DISSEMINATION OF THE CANKER BY *Epicallima Coloradella*.—No definite data were obtained on the possible dissemination of the perennial canker by this insect. Since the larvae do not usually travel from one lesion to another, however, but remain within a single canker, there is slight probability that new foci of infection are established in that way, either externally or by passage through the digestive tract. This possibility appears of little practical significance, since great numbers of spores are present in most of the cankers continuously, and their dissemination by other means, is much more common.

ECONOMIC IMPORTANCE OF THE INSECT.—This insect appears to be of little economic importance, since it seems to be a refuse feeder, living entirely, as far as these observations show, on the dead callus tissues in cankers and other wounds of apple trees. However, its intimate association with these cankers, and with the several other canker-inhabiting insects and arachnids, makes it worth while to know some of the details of this relationship.—2-5-42.

LITERATURE CITED

Busck, A. 1904. Tineid moths from British Columbia, with descriptions of new species. U. S. Natl. Mus. Proc. **27**(1375): 745–78.

Childs, Leroy. 1929. The relation of woolly apple aphid to perennial canker infection with other notes on the disease. Ore. Agr. Expt. Sta. Bul. **243.**

Cooley, Jacquelin S. 1932. Perennial canker and its relation to winter injury and to woolly aphis. Northwest Fruit Grower. **4**(2): 6, 12–13.

Essig, E. O. 1926. Insects of western North America. New York.

McLarty, H. R. 1933. Perennial canker of apple trees. Canad. Jour. Res. **8**(5): 492–507.

Treherne, R. C. 1921. Some notes on the fruit worms of British Columbia. Sci. Agr. **1**(3): 116–19.

Trumble, R. E. 1926. [*Epicallima coloradella* Moth.] Wash. State Hort. Assoc. Proc. **22:** 43–6.

Walsingham, Lord. 1888. Steps toward a revision of chambers' index, with notes and descriptions of new species. Insect Life **1**(5): 145–50.

Yothers, M. A. 1932. The relation of the Woolly aphid to perennial canker of the apple. Wash. State Hort. Assoc. Proc. **28:** 69–75.

The Life History of *Phyllophaga farcta* and *P. crassissima*[1]

H. J. REINHARD, *College Station, Texas*

The study of the two species here under consideration is a continuation of the life history investigations of Texas *Phyllophaga* begun in 1937. Both are common, potentially economic forms, widely distributed over the state. Although adults of the two species are similar in general appearance, the taxonomic relationships between them are not very close. *P. farcta* is a sluggish, semidiurnal primitive species in which the female lacks functional wings. *P. crassissima*, on the other hand, occupies an intermediate position in the *Phyllophaga* series; it is an active nocturnal form with fully developed wings in both sexes.

The life cycle data presented below were recorded under laboratory conditions. The grubs were reared individually in 4-, 6-, and 8-oz. tin ointment boxes filled with rich moist soil and kept in a cellar where temperatures were practically constant at 75° F. during the summer months and 55° F. in the winter. Grapenuts were supplied as food for the developing grubs and proved satisfactory as a growth-producing diet under the highly artificial conditions of close confinement. Other species, which were successfully reared on the same diet, have been discussed in previous papers (Reinhard 1940, 1941) covering some earlier results secured in the present life history investigations of Texas *Phyllophaga*.

Phyllophaga farcta (Leconte).—The species was originally characterized by Leconte (1856), under the family Melolonthidae, as *Lachnosterna farcta* from specimens collected in Texas. Horn (1887) redescribed the species under the same name, adding Waco and New Braunfels as specific localities of distribution. The original combination remained in use without change until Glasgow (1916) showed *Phyllophaga* Harris to be an older valid name for *Lachnosterna* Hope. The Leng catalogue (1920) lists the species as *Phyllophaga farcta* (Leconte) under the family Scarabaeidae.

The known distribution of *farcta* in Texas includes 33 counties extending west and northward from Wharton and Fannin on the east to the extreme western and northern limits of the Panhandle. Within this large area, which includes most of the range lands of the state, the grubs of *farcta* have caused widespread destruction to grasses. The injury was especially severe during 1939 and 1941 in Bosque, McLennan, Burnet and Hays Counties. Truck crops, particularly garlic and onions, are also subject to attack by the grubs. Losses ranging up to 10 per cent of the garlic crop were recorded in Lavaca County in 1939. Records taken in March 1942 show reductions up to 50 per cent in the stands of commercial plantings of onions in Williamson and

[1] Contribution No. 738, from Division of Entomology, Texas Agricultural Experiment Station.

Bell Counties, with prospects for the grubs producing additional damage as the season advances. When the beetles appear in large numbers some injury is likely to result by their feeding activities on cultivated crops. These conditions were noted in the spring of 1938 near Lockhart when an unusually heavy emergence of beetles occurred in fields of young corn in which the stands were injured to the extent of necessitating complete replantings.

In cages *farcta* beetles were observed to feed readily upon the foliage of various kinds of truck crops. Among those available for trial, spinach, carrot and lettuce seemed but slightly more attractive than beet, mustard, turnip, cabbage, rape, cowpea or onion. Young or tender cotton foliage appeared less palatable to the confined beetles than the crops listed.

The adult of *farcta* is a reddish brown, subshiny, glabrous beetle, which ranges from 18 to 24 mm. in length. Both sexes are robust in build but the form of the female is more distended behind the middle. In this sex, also, the hind tibiae are stouter, not so elongate and the pygidium is more strongly gibbous than in the male. Unusually broad hind tibial spurs are also peculiar to the species.

LIFE CYCLE.—Four reared female beetles were paired with field-collected males in separate cages on April 2, 1940 for ovipositional records. The data secured from these pairings are presented in table 1. The beetles proved rather long-lived in confinement and oviposited over a period upwards of 80 days. First oviposition was recorded on April 22, about three weeks after mating. The total number of eggs laid per female ranged from 154 to 249 and averaged slightly under 200 eggs for each individual under observation. During favorable seasons adult activities begin in March and oviposition may be well under way by early April. Late-emerging beetles, however, may remain active in the field up to the middle of August so that oviposition may extend over a period of 4 or 5 months.

The eggs when laid are pearly white, slightly elongate with rounded ends and almost parallel sides, averaging about 2 mm. in length. They begin to swell within two or three days and gradually assume a spherical shape, reaching maximum size, 3 to 4 mm., just before hatching. At this time the mandibles and portions of the head capsule of the larva are visible through the semi-transparent egg shell. The eggs are laid separately in the ground in small lumps of soil 3 to 8 inches beneath the surface.

Records on the incubation period were secured by removing the eggs from the soil and transferring them to 4- or 6-oz. ointment boxes three-fourths full of moist sterile sand. They were examined daily and kept in a rearing cellar where temperatures remained fairly uniform about as under field conditions. The duration of the incubation period, as observed under these conditions, ranged from 20 to 52 days and averaged about 35 days. Table 2, shows a summary of the records secured on 1602 eggs laid from March 29 to June 13, 1940. Shortest incubation periods were noted during May and June in temperatures averaging 65° F. or above. In the early part of the season cooler weather retards the rate of incubation and the duration of the egg stage may extend upwards of 50 days.

The newly hatched larvae are pure white in color and average 5 to 6 mm. in length. In a few hours the entire head begins to turn yellowish and continues to darken to a pale brownish color. The body soon becomes discolored following the first ingestion of soil and food. Under

Table 1.—Number of eggs laid by reared adults, *Phyllophaga farcta*, College Station, 1940.

DATE 1940	NUMBER OF EGGS LAID			
	Pair 1	Pair 2	Pair 3	Pair 4
4/2	P	P	P	P
4/9	0	0	0	0
4/18	0	0	0	0
4/22	0	0	0	4
4/29	11	6	10	4
5/5	3	4	30	18
5/10	7	8	12	11
5/14	9	18	4	6
5/20	23	14	16	19
5/27	16	19	25	14
5/31	14	21	14	26
6/7	26	28	22	17
6/13	18	26	13	13
6/21	23	17	16	5
6/28	18	12	6	9
7/5	23	16	11	4
7/14	39	10	3*	2
7/18	19	4*		2*
8/14	0*			
Total	249	203	182	154

P—paired.
* Female dead.

Table 2.—Duration of egg stage, *Phyllophaga farcta*, College Station, 1940.

Date Laid, 1940	Number of Eggs Observed	Incubation Period, Days			Temperature Average, Daily Mean
		Max.	Min.	Wt. Av.	
Mar. 29–Apr. 4	9	49	47	48.1	*
Apr. 2–9	42	52	44	46.8	*
Apr. 9–18	57	49	39	44.2	*
Apr. 18–22	80	43	39	40.3	*
Apr. 22–29	179	41	37	39.1	*
Apr. 29–May 5	158	38	32	35.0	63.2
May 5–10	178	35	30	33.7	64.0
May 10–14	150	33	29	31.1	64.6
May 14–19	215	34	29	32.7	64.8
May 19–27	123	31	25	29.1	65.0
May 27–31	179	31	24	27.3	65.0
May 31–June 7	149	28	20	24.5	66.6
June 7–13	83	26	20	24.1	68.0
Duration of incubation period				35.08	

* Temperatures not recorded.

natural conditions larvae feed upon organic matter in the soil and upon the roots of various kinds of plants or crops available. As previously mentioned, however, the larvae reared individually in small containers in this study were fed upon grapenuts. Each individual was started on this diet immediately after hatching and an adequate supply of the food was maintained throughout the period of larval development. Two molts occur during the feeding period and the majority of the grubs attain full growth by November. The winter is passed in the third instar or mature larval stage. Pupation from this stage does not occur until the late summer or early fall of the following season.

A brief summary of the data recorded on larval development is presented in table 3. The first and second instars averaged approximately 38 and 56 days, respectively. The third larval instar is much more protracted; it averages about 341 days, with extremes ranging from 315 to 395 days. The heavy mortality indicated for this developmental stage occurred largely during the period of aestivation in 1941. No explanation for this apparently excessive mortality of the grubs can be given at present. However, it is not peculiar to the species here under discussion and seemingly therefore attributable to some unfavorable condition imposed in the rearing methods employed. Based upon weighted averages calculated for the length of all instars, the total larval period averaged about 435 days indicating a 2-year cycle for the species in the latitude of College Station.

The newly transformed pupa is creamy white in color but gradually turns a reddish brown. It averages about 26 mm. long and 10 mm. wide. Pupation occurs within a cell formed in the soil by the mature larva. During the process of pupation the larval skin splits backward from the head and the pupa gradually works its way out by twisting or wriggling movements. The cast skin is gradually pushed to the extreme tip of the abdomen where it remains loosely attached. The period of pupation as observed in the laboratory is from July 10 to September 29, the bulk of the individuals transforming in August.

Table 3.—Duration of larval stage, *Phyllophaga farcta*, College Station, 1940–41.

Instar	No. of Larvae Observed	Number of Larvae in Instar for Period Specified						Weighted Average, Days
		30–44 days	45–59 days	60–86 days	315–329 days	330–364 days	365–395 days	
First	740	678	58	4				38.22
Second	603	66	282	255				56.43
Third	125				18	104	3	340.87
Total larval period								435.42

Table 4.—Duration of pupal stage, *Phyllophaga farcta*, College Station, 1941.

Sex	No. of Pupae Observed	No. of Individuals in Pupal Stage for Days Specified														Weighted Average Days
		22	23	24	25	26	27	28	29	30	31	32	33	34	35	
Male	61		3	10	6	14	10	3	4	4	2	1	2	1	1	26.92
Female	64	1	6	8	5	13	10	7	7	1	1	2	1	2		26.72
Average duration of pupal period																26.82

The records secured on duration of the pupal stage are summarized in table 4. The average time required for development was about 27 days, with a minimum of 22 days and a maximum of 35 days. Weighted averages calculated from 125 complete records indicated no significant difference in the rate of development between sexes. The daily mean temperatures averaged about 73.5° F. during the period of these observations.

SUMMARY.—The beetles emerge in maximum numbers during April and egg deposition is well underway during the same month. The average duration of the egg stage is 35 days. Larvae, with access to ample suitable food, develop rapidly and attain full growth during the fall. The overwintering larvae remain quiescent during the following summer until after mid-July when pupation begins. The larval stage was found to average 435 days. Pupae are commonly present during August and September but the adults transforming at this time remain in the pupal cells until the following spring, thus completing a two-year life cycle.

This is one of the common and well known forms among the species of southwestern *Phyllophaga*. Blanchard (1850) originally described it under the name *Ancylonycha crassissima*. Six years later Lœconte (1856) described *Lachnosterna obesa* and *L. robusta*, which Horn (1887), who studied the types, pronounced synonyms of *crassissima*. At the same time, this author described *Lachnosterna generosa* from a single male specimen from Texas. Glasgow (1916), who studied the genitalia of this type, included it, in addition to the species previously indicated by Horn, as a synonym of the present species. Leng (1920) repeats this synonymy with a doubt. Most of the important references to the species in our literature have been listed by Travis (1934).

The species is widely distributed over

Table 5.—Number of eggs laid by reared adults, *Phyllophaga crassissima*, College Station, 1940.

Date, 1940	Number of Eggs Laid									
	Pair 1	Pair 2	Pair 3	Pair 4	Pair 5	Pair 6	Pair 7	Pair 8	Pair 9	Pair 10
4/3	P	P	P	P	P	P	P	P		
4/9	0	0	0	0	0	0	0	0	P	P
4/18	0	0	0	0	0	0	0	0	0	0
4/22	0	0	7	0	3	0	0	0	0	0
4/29	8	0	8	5	5	0	0	8	0	0
5/5	0	0	3	4	3	2	0	0	4	7
5/12	0	0	9	0	11	12	2	8	6	4
5/17	13	20	11	20	16	0	14	15	21	30
5/23	16	6	14	15	27	19	9	10	13	11
5/31	3	9	12	8	16	14	23	18	18	2
6/8	11	17	4	11	9	17	16	29	27	46
6/14	2	10	9	12	8	5	6	2	19	12
6/21	0*	9	0*	17	10	24	3	4	16	23
6/28		0		3	6	4*	0*	0*	10	18
7/4		0*		0*	0*				0	2
7/14									0*	2
7/18										0*
Total	53	71	77	95	114	97	73	94	134	157

P—paired.
* Female dead.

the eastern half of the state with definite records of occurrence available from 54 countries extending westward to Sutton and Menard Counties and southward to Bexar, Wharton, and Brazoria Counties. Within this area, *crassissima* is one of the most frequently abundant species but there are very few, if any, definite records concerning its economic importance. The grubs have been reported from strawberry beds, lawns, cotton fields, etc., but without any precise information concerning the injury produced. However, the abundance of the species over a large part of Texas indicates its importance as a potential pest, which, during favorable seasons, may cause extensive losses to various truck, field and forage crops.

The adult is a good-sized beetle capable of consuming a considerable amount of foliage and during periods of heavy beetle flights extensive defoliation of the preferred host plants often occurs. In oviposition cages the beetles fed readily upon oak, elm and persimmon; they also were commonly collected from these plants in the field. Additional food plants, as determined by field collections, include white ash, hackberry, plum, apple and hawthorn.

Horn (1887) described the beetle as one of the most broadly ovate in our fauna, approaching *farcta*, but less ventricose. The color is variable ranging from light reddish to dark brown, with a thin but usually distinct whitish bloom on the elytra of well preserved specimens. Aside from its distinctive form and coloration the species is characterized by the foveolate apical ventral segment in the male and the smooth shiny, gibbous pygidium in the female. The beetles range from 17 to 22 mm. in length and 8.5 to 12 mm. in width.

LIFE CYCLE.—The data presented below were secured by similar methods and under the same environmental conditions as described on the preceding pages for *farcta*. Since the egg, larval and pupal stages in *crassissima* are quite similar to the corresponding stages briefly discussed under the preceding species, descriptions of the immature stages in *crassissima* are omitted to save space. Even the developmental periods check closely in the two species but a summary of the detailed life cycle data is presented in comparable tabulations below.

Table 6.—Duration of egg stage, *Phyllophaga crassissima*, College Station, 1940.

Date Laid 1940	Number Eggs Observed	Incubation Period, Days			Temperature Average, Daily Mean
		Max.	Min.	Wt. Av.	
April 22–29	7	36	35	35.57	[1]
April 29–May 5	27	36	30	31.63	63.2
May 5–12	14	37	32	34.64	64.0
May 12–17	140	34	27	28.63	64.8
May 17–23	80	29	24	26.15	64.8
May 23–31	85	27	23	25.25	65.0
May 31–June 8	139	25	16	19.88	66.6
Duration of incubation period				25.60	

[1] Temperatures not recorded.

Ten pairs of reared beetles were caged separately on April 3 and 9, 1940 for records of the number of eggs laid. The figures secured are listed in table 5. The preoviposition period among these individuals ranged from 19 to 44 days and averaged about 28 days. The total number of eggs per pair ranged from 53 to 157 and averaged about 97 eggs, as compared with nearly 200 eggs in *farcta*. The ovipositional period as determined for these confined beetles averaged about 53 days and extended from April 22 to July 14. Normally maximum beetle emergence occurs during April and the bulk of the eggs are deposited during the same and following month. However, stragglers at times appear active up to the latter part of August which may prolong the period of oviposition in the field.

The data recorded on the duration of the egg stage are briefly summarized in table 6. In mean temperatures ranging from about 63 to 66.5° F., the eggs incubated in 16 to 36 days and for the entire period of observation the egg stage aver-

Table 7.—Duration of larval stage, *Phyllophaga crassissima*, College Station, 1939–41.

Instar	No. of Larvae Observed	Number of Larvae in Instar for Period Specified							Weighted Average, Days
		24–29 days	30–44 days	45–59 days	60–71 days	328–364 days	365–395 days	396–406 days	
First	254	17	202	33	2				36.44
Second	239	12	108	112	7				43.79
Third	109[1]					81	20	3	355.00
Total larval period									435.23

[1] Five short-cycle larvae not included in calculations.

aged about 26 days, as compared with 35 days for *farcta* eggs incubated under similar conditions.

As in the case of the preceding species two molts are required for the larva to attain full growth and the bulk of a given brood normally passes the first winter in this developmental stage. Pupation does not occur until late in the following summer after which transformation to the adult stage takes place, mainly during September and October. The beetles remain in the pupal cells to pass the second winter and emerge with the advent of favorable temperatures the following spring to complete the normal two-year life cycle. Occasionally, however, grubs of this species pupate shortly after attaining maturity and complete their transformation to the adult stage in one growing season. The few individuals displaying an abbreviated or one-year life cycle appeared normally developed in all respects. During 1939 and 1940, 254 newly hatched grubs were caged for rearing; only 109 of these were carried through to the adult stage. Five of the latter number were short-cycle individuals and are not included in the calculations of the final larval period as summarized in table 7. The duration of the first and second larval instars ranged from 24 to 71 days, and averaged 36 to 44 days, respectively. The third larval instar, which includes records on 104 individuals, averaged 355 days, with extremes ranging from 328 to 406 days. The total time required for the larval stage, as determined by weighted averages of all available records, was 435 days. This figure checks closely with the corresponding stage in *farcta*, which was reared under similar conditions.

Records taken on the duration of the pupal stage are briefly summarized in table 8. The time required to complete pupal development averaged about 26 days for both sexes. The minimum length of time in the stage was found to be 21 days and the maximum 35 days. In the laboratory grubs first began to pupate on July 28; the majority of individuals transformed during August and last pupation occurred on September 14. During this period the effective temperatures averaged about 74° F.

Table 8.—Duration of pupal stage, *Phyllophaga crassissima*, College Station, 1940 and 1941.

Sex	No. of Pupae Observed	No. of Individuals in Pupal Stage for Days Specified															Weighted Average, Days
		21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	
Male	56		1	6	9	11	7	7	3	3	2	4	1	1	1		26.36
Female	53	2	4	5	8	3	8	7	2	6	1	3	1	1	1	1	26.34
Average duration of pupal period																	26.35

SUMMARY.—As determined in these studies the complete life cycle of a generation of the present species may be summarized as follows: Overwintering beetles frequently begin to emerge during late March and may remain active in the field up to mid-August. Eggs are commonly present during April and May and at this time the incubation period averages about 35 days. The grubs molt twice during the feeding period and attain

maturity by September or October. The winter is passed in this developmental stage and the grubs remain quiescent until the following July or August when pupation occurs. The average length of the larval stage is 435 days. Pupation occurs commonly during August and September and approximately 27 days are consumed in this stage for transformation to adults. The latter remain in the pupal cells during the following dormant season and emerge the next spring to complete a normal two-year life cycle.—4-1-42.

LITERATURE CITED

Blanchard, Emile. 1850. Catalogue de la Collection entomologique. Classe des insectes Ordres des Coleopteres. **1,** 128 pp. Paris Museum d'Histoire Naturelle.

Leconte, John L. 1856. Synopsis of the Melolonthidae of the United States. Jour. Acad. Nat. Sci. Phil. **3**:(2) 225–88.

Horn, Geo. H. 1887. Revision of the Species of Lachnosterna of America North of Mexico. Trans. Amer. Ent. Soc. **14:** 209–96.

Glasgow, R. D. 1916. Phyllophaga Harris (Lachnosterna Hope): a revision of the synonymy, and one new name. Bull. Illinois Lab. Nat. Hist. **11:** 365–79.

Leng, Charles W. 1920. Catalogue of the Coleoptera of America North of Mexico. 470 pp.

Travis, Bernard V. 1934. Phyllophaga of Iowa. Iowa State College Jour. Sci. **8:** 313–65.

Reinhard, H. J. 1940. The life history of Phyllophaga lanceolata (Say) and Phyllophaga crinita (Burmeister). JOUR. ECON. ENT. **33:** 572–78.

Reinhard, H. J. 1941. The life history of Phyllophaga tristis (Fabricius) and allied forms. JOUR. ECON. ENT. **34:** 526–32.

Control of Stablefly, or "Dog Fly," Breeding in Shore Deposits of Bay Grasses

W. E. DOVE and S. W. SIMMONS,[1] *U. S. Department of Agriculture, Bureau of Entomology and Plant Quarantine*

The stablefly or, "dog fly," *Stomoxys calcitrans* (L.), breeds extensively in certain marine grasses deposited along the shores of bays, sounds, and inlets of northwestern Florida (Simmons & Dove 1941a). Two principal species of bay grasses *Halodule wrightii* Aschers. and *Thalassia testudinum* Koenig and Sims, are of common occurrence, but in some areas *Cymodocea manatorum* Aschers. is mixed with *T. testudinum* and becomes an important breeding material. These grasses grow on the bottom of certain portions of shallow bays and sounds, and during the summer and fall the green leaves break off and are deposited by tides in drifts along the beaches. In such locations drifts undergo fermentation and furnish suitable places for the development of dog flies.

From evidence obtained in small-scale tests made in the field the writers previously outlined a procedure for treating grass deposits to prevent development of dog flies (Simmons & Dove 1941b). During 1941 a large-scale application of the methods afforded an opportunity for further detailed studies. The present paper presents tests and observations demonstrating that eggs, larvae, and pupae were killed by practical spray treatments of bay grass deposits with creosote in diesel oil, that such treatments prevented infestations, and that the adult fly population was markedly reduced in the treated areas.

METHODS AND MATERIALS.—Bay-grass deposits were sprayed with a mixture consisting of creosote oil (Federal specification TTW-556) 1 part and diesel oil 3 or 4 parts.

At an average pressure of about 650 pounds at the sprayer the insecticides were applied through 100 to 400 feet of half-inch high-pressure hose. The spray machines, with tank capacities of 400 or 600 gallons, were mounted on shallow-draft barges 14 by 25 by 2.5 feet deep and were towed near the water's edge with small shallow-draft boats. In very shallow water the spray barge was pushed by a laborer or propelled by an outboard motor. On the barges extra material was carried in 50-gallon drums and was used for reloading the tanks. Where two spray barges operated in close proximity, an additional barge with a capacity of 4,000 to 6,000 gallons of material was used to supply the spray barges. The material was applied

[1] The writers are indebted to Mike Wright for some observations herein reported and to H. F. Tate for suggestions on some mechanical procedures in practical spray operations.

FIG. 1.—A power sprayer, mounted on a barge and towed by a shallow draft boat, was used in treating tidal deposits of grass on the shores of bays and sounds for control of dog fly breeding places in northwestern Florida.

by a nozzleman on the shore, and other laborers were used to pull the hose or to break up grass deposits with pitchforks.

In practice it was found that better results were obtained, spray material was conserved, and time was saved when a pitchfork was used to tear apart the deep deposits of grass before they were sprayed; also, a test to determine the penetration obtained at 650 pounds pressure for 1 minute clearly demonstrated that this observation was correct. Eight piles of well-packed, lightly infested *Thalassia testudinum*, each measuring 6 by 2 by 2 feet, were selected on September 11, and on September 17 six of them were sprayed intact, one was sprayed after being scattered, and one was left untreated. In the undisturbed piles the depth of penetration ranged from 6 to 15 inches, an indication that in such a practice the complete penetration of grass of this depth is not assured without the use of excess material. The scattered grass, averaging 6 inches in depth, was found to be well treated. Although the same quantity of material was used on the deeper piles, it was not sufficient for complete penetration, which should be attained to insure a complete kill.

From September 4 to October 20, 1941, eight barge-spray units (Fig. 1) were operated in northwestern Florida with funds available to the United States Public Health Service in cooperation with the Bureau of Entomology and Plant Quarantine of the United States Department of Agriculture. The eight units applied 208,350 gallons of spray material on tide drifts of grass averaging 31.3 inches wide and 7.6 inches deep, for a distance estimated at 286.43 miles. In treating this amount of grass it was necessary to tow the barges along approximately 701.55 miles of shore line of bays and sounds in Santa Rosa, Okaloosa, Bay, Gulf, and Franklin counties of northwestern Florida for a sufficient number of treatments to insure good control. This mileage represented not only the first treatment, but a second coverage in some places and even a third in some portions of East Bay and St. George Sound. Treatments were applied on approxi-

mately 40.8 per cent of the shore line. It was estimated that the difference between the amount of grass sprayed during the first treatment and that sprayed during the second treatment was less than 1 per cent.

A record of spraying operations accomplished by each of the eight units is given in table 1.

FIG. 2.—Natural breeding places of dog flies are provided by tidal deposits of grass on portions of the shores of various bays and sounds of northwestern Florida.

The total cost of the control operations was $56,039.46. This did not include the purchase of spray machinery, automotive equipment, and two of the eight boat-barge units used. The cost of spray material was about 40 per cent of the total, or $74.26 for each mile of grass treated. This is equivalent to $30.33 per mile of shore line covered. The total cost was $195.65 for each mile of grass treated, or $79.88 per mile of shore line covered. Approximately 27 per cent of the cost was expended for salaries and wages, and 33 per cent for equipment, supplies and travel.

INFESTATIONS IN UNTREATED GRASS.—In most instances grass was treated before the insects developed to the pupal stage, and untreated grass therefore consisted principally of fresh deposits containing only eggs and larvae. It was possible at times, however, to collect several dozen pupae from 1 square foot of untreated material.

Immature specimens were easily found when in the third larval stage. Counts made on September 25 at 7 stations along St. George Sound showed a range of 3 to 30 third instars per square foot, with an average of 11.3. First instars were difficult to find, but as many as 100 were observed in a square foot of grass, and no doubt more were present. During the period from September 29 to October 2 counts made at 16 stations on St. George Sound ranged from 5 to 20 larvae per square foot, with an average of 15.4. Practically all these were third instars and undoubtedly many first instars were overlooked. Accurate egg counts were difficult to make in the bay grass, but the finding of a thousand or more eggs per square foot of surface area was not uncommon.

To determine the adult population from untreated grass, cages 6 by 6 by 3 feet were erected over infested material and the captured flies were counted. The cages were well constructed, and no flies entered from the outside. On September 19 one cage was placed over 6 cubic feet of infested grass that was about 6 days old. The grass was composed of a mixture of *Halodule wrightii*, *Thalassia testudinum*, and *Cymodocea manatorum* and was piled above the normal high-tide mark. On September 29 the first emergence occurred and by October 27 a total of 231 adult dog flies had emerged, or 38.5 flies per cubic foot of grass.

Another cage was erected on September 19 over 16 cubic feet of mixed grass infested with larvae. This grass was also placed well above the normal high-tide mark, but was inundated by a hurricane on October 7. On September 29 the emergence began, and it continued for 20 days, producing a total of 356 adult dog flies, or 22.3 flies for each cubic foot of grass.

Table 1.—Record of spray operations in the control of dog flies along the shores of bays and sounds in northwestern Florida from September 4 to October 20, 1941.

Spray Unit No.	Location	Material Used, Gallons	Shoreline Covered, Miles	Grass Deposits Treated Miles	Shoreline Treated, Per Cent	Average Width of Grass, Inches	Average Depth of Grass, Inches	Material per Mile of Grass Treated, Gallons[1]
1	Santa Rosa Sound	31,100	75.20	45.93	61.0	40.19	6.25	677
2	Santa Rosa Sound	22,600	57.60	22.15	38.4	52.7	8.6	1,020
3	Choctawhatchee Bay	21,550	77.83	32.71	42.0	10.5	5.4	658
4	East Bay, West Bay, and St. Josephs Bay	41,450	153.25	37.64	24.5	26.6	6.5	1,101
5	East Bay, West Bay, and St. Josephs Bay	26,500	103.50	32.95	31.8	22.3	6.2	804
6	Crooked Island Sound, St. Andrews Bay, and West Bay	22,020	148.00	63.38	42.8	20.69	8.96	347
7	St. Josephs Bay	22,010	40.92	19.11	46.7	42.0	5.64	1,151
8	St. George Sound	21,120	45.25	32.56	71.9	54.0	12.4	648
Average (weighted)		26,043	87.69	35.80	40.8	31.3	7.6	727.4
Total		208,350	701.55	286.43				

[1] The average number of gallons used per mile ranged from 696.6 for the first application to 768.3 for the second, with an average for the season of 727.4 gallons.

A third cage was erected on September 22 over 16 cubic feet of undisturbed mixed bay grasses in a tide drift receiving a normal deposition of eggs. Emergence of adults started on October 1, and by October 6 a total of 390 adult dog flies had emerged, or an average of 24.4 flies per cubic foot of grass. A tropical hurricane on October 7 destroyed the cage and prevented further observations. Since cages 1 and 2 produced flies for 20 and 30 days, respectively, it is evident that additional flies would have emerged from cage 3 if it had not been destroyed.

The average infestation for the three cages was 25.7 flies per cubic foot of grass. The magnitude of such an infestation can be visualized when it is remembered that approximately 286 miles of grass deposits were treated, which were on an average 31.3 inches wide and 7.6 inches deep.

Since in these tests the grass was caged at a stage when it was favorable for receiving eggs and was prevented from obtaining further oviposition, the populations in the cages were those resulting from exposure to adult flies for only 1 week and would represent only a portion of the probable population.

MORTALITY OF IMMATURE STAGES OF DOG FLIES IN TREATED GRASS.—Bay grass that had been heavily infested with eggs was examined in dozens of instances at various intervals after spraying, and no live larvae were ever found. On September 19 two lots of grass heavily infested with eggs were sprayed in the usual manner with a mixture of creosote 1 part and Diesel oil 3 parts, and portions of the grass containing many eggs were placed in Petri dishes for detailed observations. No eggs hatched, and the treated eggs were discarded on September 27, but in the untreated checks a good hatch was obtained. In other tests several lots of green grass infested only with eggs were sprayed with a mixture of creosote and oil and were caged for recovery of any flies that developed. In all instances where the treatment was thorough no flies emerged, whereas the check cages showed a good number of flies.

In large-scale spray tests substantially 100 per cent of the larvae were killed in well-treated grass. Many miles of larval-infested grass were examined at various intervals subsequent to spraying with creosote and oil, and in no instance were any living larvae found in the treated material.

Several 6-by-6-foot cages erected over sprayed grass that had been infested with

Table 2.—Persistence of creosote in treated bay grass in northwestern Florida in 1941.

Station No.	Locality	Species of Grass	Dimensions of Drift			Period During Which Grass Retained Creosote, Days
			Length, Yards	Width, Inches	Depth, Inches	
1	St. Josephs Bay	*Thalassia testudinum*	800	36	8	22
2	East Bay	*Halodule wrightii*	500	30	9	18
3	East Bay	*T. testudinum*	900	48	8	26
4	St. George Sound	*T. testudinum* and *Cymodocea manatorum*	2,640	48	6	25
5	East Bay	*T. testudinum*	3,500	36	6	30

larvae recovered no flies, but the three cages used as checks captured 231, 356, and 390 adult dog flies, or 25.7 flies per cubic foot of grass. In 19 tests with infested bay grass in 1940 complete kills of larvae were obtained, and observations made on the treated deposits in 1941 did not reveal any living larvae. These results were confirmed in tests on infested peanut litter and celery strippings.

Pupal mortality was also substantially 100 per cent on well-treated grass. Since most of the grass was sprayed soon after deposition of eggs and before the pupal stage was attained, there was little opportunity for large-scale observations on pupal mortality. In a detailed test 290 pupae were placed in each of 2 piles of untreated bay grass, *Halodule wrightii*, measuring 2 by 2 by 1 feet, and were treated with creosote 1 part and Diesel oil 4 parts. The test was conducted beneath a screened shed, where half the pupae were placed 4 inches beneath the surface and half at a depth of 8 inches. One pile was treated with 3,000 cc. of the creosote-Diesel oil mixture, and the other pile was left untreated as a check. Both piles were caged and kept under observation for 53 days. The treated grass produced no flies, whereas from the check plot 157 adults, or 54.1 per cent, emerged.

Treatment of Green Uninfested Grass to Prevent Infestation.—During these investigations large quantities of green uninfested grass were treated to prevent infestation. Periodic examinations were made at observation stations, but in no instance were any infestations found in grass that had been treated with either a 1-to-3 or a 1-to-4 mixture of creosote and Diesel oil.

An additional test with 8 lots of green uninfested *Thalassia testudinum* measuring 2 by 2 by 1 feet was made near a cattle corral where good infestations were usually obtained. Four lots were treated, 1 with 3,000 cc. of a 1-to-3 mixture of creosote and oil and 3 lots with the same quantity of a 1-to-4 mixture. The remaining 4 lots were left untreated as checks. After the 8 lots were exposed for infestation for 10 days, they were caged for recovery of adult flies. As a result of the efficiency of the control operations, there was a low adult dog fly population. The 4 check cages, however, produced 19, 8, 8, and 4 flies, or a total of 39, whereas from the lots of treated grass no flies emerged.

From these tests and from the observations made in the field on large-scale treatments, it is concluded that green uninfested grass, if properly treated, will not subsequently breed dog flies.

Persistence of Creosote in Treated Grass.—In 1940 experiments indicated that creosote met the durability requirements occasioned by tidal action on deposits of grass, and in 1941 further tests substantiated this finding. In addition to observations made during the control program, the results of tests made at five stations are shown in table 2.

The data in table 2 do not represent the maximum period during which creosote remained in the grass, but rather the period during which the grass was examined. On the last examination the grass was found to be well covered and there was no breeding. Because the grass will not breed dog flies after it has passed the proper stage of fermentation, the protection given would have been sufficient to prevent breeding.

On September 20, 16 cubic feet of mixed bay grass, heavily infested with larvae, was sprayed and put in cages below the high-tide water mark, where it was subjected to severe washing each day. On September 30, or 10 days subsequent to

treatment, the grass still retained a sufficient quantity of creosote to prevent further breeding. The inability of dog flies to breed in the treated grass demonstrates beyond any doubt that creosote is a lasting larvicide in bay-grass deposits regardless of strong tidal action.

COMPARATIVE DOG FLY POPULATIONS IN TREATED AND UNTREATED AREAS.—The dog fly population was greater at the beginning of the control program than at any subsequent time, and when the control work was started the bay-grass deposits in different locations were found infested with immature stages of dog flies. It is believed that the numbers of adult flies present would have been sufficient to produce a major infestation if control work had not been initiated. The spray operations began on September 4, about 1 month later than the normal time, and were continued until October 20.

Daily fly-population counts were made on the same herds of range cattle throughout the area under treatment as well as in adjacent untreated areas. On August 16 in the vicinity of Santa Rosa Sound the cattle averaged 50 flies per animal, and at Tyndall Field near Panama City from 15 to 25 flies were observed per man per minute, or as many as 40 to 50 flies per man. On September 8 the flies were more numerous than at any previous time. On Santa Rosa Sound, where breeding had occurred prior to control operations, cattle averaged from 350 to 500 flies. Nearer Panama City where several days of spraying had been accomplished, the cattle averaged only about 20 flies per animal.

On September 24 and 25, 385 animals in 7 localities extending throughout the control area showed an average of less than 2 flies per animal and a maximum of 16. On October 4 observations made at various points on approximately 500 cattle between Pensacola and Port St. Joe showed an average of less than 2 flies per animal, whereas in the Apalachicola section, which was the eastern extremity of the control area, the fly population averaged 24 per cow.

On October 11 cattle between Fort Walton and Port St. Joe averaged about 2 flies per animal, and at Carrabelle, where no control was undertaken, but where some protection was afforded from the Apalachicola area, the average was 9 flies per animal. In the vicinity of Big Lagoon, just west of the treated area, the flies on cattle ranged from 6 to 200, while 4 animals averaged 225 each and 1 horse had 500 flies.

The difference in the fly population of Apalachicola and Carrabelle for the week ended October 11 is shown in table 3. The former was in the control area but received some flies from the adjacent untreated Carrabelle area.

Table 3.—Dog fly populations in the Apalachicola and Carrabelle areas on October 11, 1941.

ANIMAL	AVERAGE NUMBER OF DOG FLIES PER ANIMAL PER WEEK	
	Apalachicola (Treated)	Carrabelle (Untreated)
Man	5	25
Cattle	66	231
Dog	7	14
Pig	17	27

On November 6, in the vicinity of a bay grass breeding area on East Pensacola Bay, cattle averaged 250 flies per animal, whereas about 15 miles eastward in the treated area the cattle averaged only 15 flies per animal.

Two periods of high fly population occurred at Apalachicola, but neither was long or extremely severe. One of these followed the tropical hurricane of October 7, which caused flies to drift in from the untreated areas. During this period cattle at Apalachicola averaged 184 flies per animal, but in the untreated Carrabelle area the average was 380 flies per animal. Another small outbreak occurred from October 21 to 24, following a cool wave accompanied by several days of southeasterly winds, which undoubtedly caused flies to drift in from the adjoining untreated area just east and southeast of Apalachicola.

Daily counts made at Apalachicola from September 23 to October 25 showed a weighted average of 39 flies per cow, 3 per man, and 6 per dog, while at Carrabelle counts made daily from October 2 to 24 showed 72 flies per cow, 14 per man, and 12 per dog. The average daily population on cattle at Apalachicola compared with that at Carrabelle, where no treatments were made, is shown in figure 3.

From these population studies and from the fact that residents agree that 1941 was the only year in which dog flies were not

present in outbreak numbers, it must be concluded that the control operations were highly successful. The extremities of the area treated, however, received some flies from the adjacent untreated area, and in any future control work the treated area should be extended.

NATURAL CONTROL.—In 1941 a distinct advantage was gained from natural control. The fact that drifts of grass were formed about 1 month later than usual partly compensated for the late beginning of the spray operations; also, when the adult fly populations were reduced to a low point, three species of dragonflies, *Anax junius* (Drury), *Pachydiplax longipennis* (Burm.), and *Tramea lacerata* (Hagen), appeared to be effective in obtaining a further reduction of the pests. The dragonflies were most abundant during October, and about sunset they were observed to capture dog flies. Other predators that have been observed to capture dog flies at various seasons are the horse guard, *Stictia carolina* (F.), a predacious wasp, *Vespula squamosa* (Drury), and a bee, *Xylocopa micans* (Lep.) (Simmons & Dove 1941a).

SUGGESTIONS FOR FUTURE WORK.—The success or failure of any insect-control program depends upon a timely application of control measures. The use of water as a substitute for Diesel oil with creosote (Simmons & Dove 1942) is recommended as a new procedure for control work in the future. In addition, it is suggested (1) that control operations be extended to at least 50 miles from the places to be protected, because of the drifting of dog flies with the breezes, (2) that an experienced control operator serve as foreman, scout, and supervisor of the spray work of each unit, (3) that during the control season continued observations be made to detect breeding places and populations of adult flies so that treatments may be applied promptly, (4) that complaints of fly annoyance be investigated promptly to determine the seriousness and probable origin of the flies, and (5) that the effects of any storms be investigated promptly so that deposits of new grasses may be treated before flies are produced

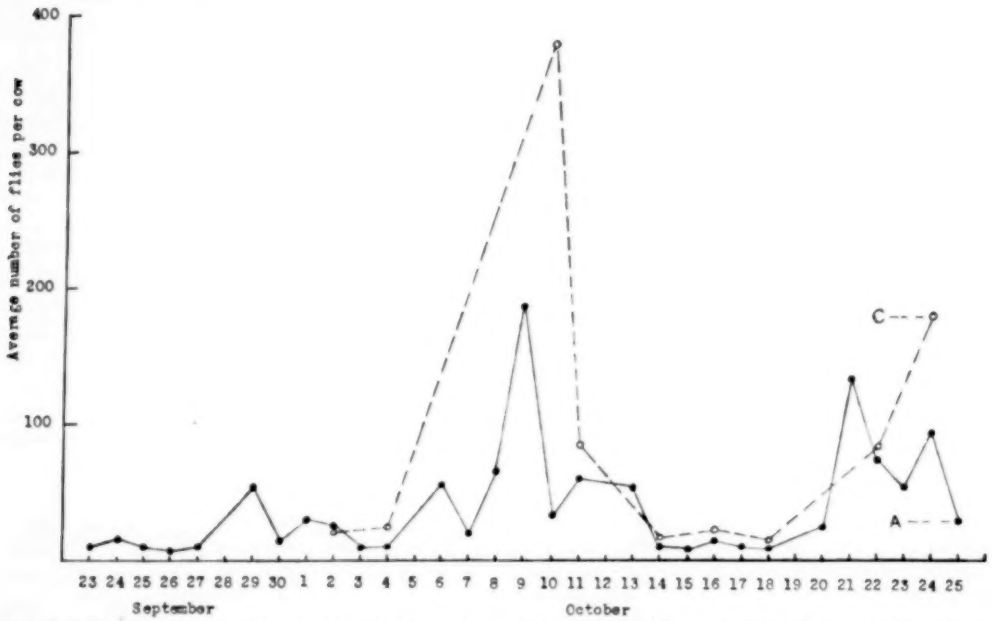

FIG. 3.—Daily average number of dog flies found on cattle at Carrabelle and at Apalachicola, Fla., September 23 to October 25, 1941.

SUMMARY.—In studies of the stablefly, or "dog fly," *Stomoxys calcitrans* (L.), in grass deposits along the shores of bays and sounds of northwestern Florida, eggs were commonly found at the rate of 1,000 per square foot of grass and larvae at the rate of 15.4 per square foot. From material in 3 cages 38.5, 22.3, and 25.7 flies emerged per cubic foot of grass. Spray treatments

of infested grasses with creosote in Diesel oil resulted in a complete kill of eggs, larvae, and pupae, and there was no subsequent breeding of the flies in the treated grasses. The creosote was observed to remain in the grass for 18 to 30 days, or long after the time for fermentation had passed. Large-scale spray operations reduced the fly population in the treated area to less than 2 flies per animal on cattle. Predatory dragonflies identified as *Anax junius* (Drury), *Pachydiplax longipennis* (Burm.), and *Tramea lacerata* (Hagen) were observed to feed on dog flies.—4-2-42.

LITERATURE CITED

Simmons, S. W., and W. E. Dove. 1941a. Breeding places of the stablefly or "dog fly," *Stomoxys calcitrans* (L.), in northwestern Florida. JOUR. ECON. ENT. **34**(3): 457–62.

Simmons, S. W., and W. E. Dove. 1941b. Control of dog fly breeding in beach deposits of marine grasses. U. S. Dept. Agr. Bur. Ent. and Plant Quar. E-541.

Simmons, S. W., and W. E. Dove. 1942. Creosote oil with water for control of the stablefly or "dog fly" in drifts of marine grasses. JOUR. ECON. ENT. **35**(4): 589–92.

Creosote Oil with Water for Control of the Stablefly, or "Dog Fly," in Drifts of Marine Grasses

S. W. SIMMONS and W. E. DOVE,[1] *U. S. Department of Agriculture, Bureau of Entomology and Plant Quarantine*

The stablefly, or "dog fly," *Stomoxys calcitrans* (L.), breeds extensively in tide drifts of grasses that are deposited along the shores of certain bays, inlets, and sounds of northwestern Florida (Simmons & Dove 1941a). In 1940 a method for the control of breeding places of this pest was developed which consisted of spraying the bay grass with a mixture of creosote, 1 part, and diesel oil, 3 or 4 parts. This was accomplished by the use of a power sprayer mounted on a barge and towed near the shore line (Simmons & Dove 1941b). In September and October of 1941 this method was successfully used in a large-scale program for the control of dog flies along the coast of northwestern Florida.

Previous studies have shown that mortalities of dog fly larvae treated with mixtures of creosote and diesel oil depend almost entirely upon the action of the creosote, and the experiments reported herein were designed to develop a cheaper diluent or substitute for the oil. The present paper reports that an emulsion made by the agitation of creosote with water, obtained from the bays where spraying operations are conducted, proved to be entirely satisfactory as a substitute for the mixture of creosote and diesel oil. It shows that the use of a mixture containing water from a bay or sound can effect a considerable saving in future operations for control of dog fly breeding in tidal drifts of marine grasses.

METHODS AND MATERIALS.—A standard power sprayer with the usual two-blade propeller-type agitators was used without any alteration. Creosote is not soluble in water, but observations made on samples obtained during the operations showed that the regular mechanical features of the sprayer maintained a satisfactory emulsification without the use of an emulsifier. Initial tests were conducted in April 1941, when a creosote-bay water mixture of known proportions was tested for emulsification by spraying at 750 pounds pressure through 300 feet of hose, from a 400-gallon spray tank. Samples were collected in graduated cylinders from the nozzle at the end of the hose and were allowed to settle until the creosote and water were completely separated. The creosote could then be measured and its concentration in the mixture determined as it left the nozzle. The data recorded for different periods of agitation are shown in table 1.

It will be noted that there was a maximum variation in creosote content of only 4 per cent between the tank mixtures and

[1] The writers wish to express their appreciation for the assistance of Mike Wright, of the Bureau of Entomology and Plant Quarantine.

samples, a difference that does not appear especially objectionable. Since the mixture is not applied to tillable soil and is in a high dilution where it is possible to correct the distribution by proper use of the nozzle, it appears that the variation in creosote content is of minor importance. In September and October 1941 a total of 17,750 gallons of creosote-water emulsion, made from 1 part of creosote and 3 parts of water, was employed. The mixture was

Table 1.—Creosote content of creosote-bay-water mixture before and after various periods of agitation.

Material in Tank When Sample Was Taken, Gallons	Agitation Period Before Sample Was Taken, Minutes	Creosote in Original Mixture in Tank, Per Cent	Creosote in Sample, Per Cent
400	5	5	7.0
266	20	5	4.5
200	28	5	5.0
200	5	10	11.0
100	15	10	14.0
10	25	10	10.0

sprayed at an average gage pressure of about 650 pounds, through 100 to 300 feet of half-inch hose. All sprayed grass deposits were carefully observed and if there was any variation in the distribution of the creosote oil in the mixture, it could not be determined by visual examination. No mechanical difficulties were encountered with any of the spray machines which were traceable to the use of the creosote-water emulsion. After weeks of use the machines were apparently in as good mechanical condition as were those using creosote mixed with oil. The most important observation was that with the use of water or any other diluent it is necessary to obtain clean creosote not previously used for some other purpose. The creosote meeting government specifications TT-W-556, which is the equivalent of the American Wood Preservers Association Specifications 4-C, was found to be satisfactory.

RATES OF APPLICATION.—In the tests of September and October 1941 the 17,750 gallons of creosote-water emulsion was applied to an estimated distance of 14.07 miles of grass, which represented 46.85 miles of shore line on St. George Sound, St. Josephs Bay, and East Bay. The treated-grass deposits consisted of blades of *Thalassia testudinum* Koenig & Sims, *Halodule wrightii* Aschers., and *Cymodocea manatorum* Aschers., or mixtures of these. It is calculated that the average rate of application was 1261.5 gallons of material per mile of grass actually treated. This was in excess of the 727.4 gallons of creosote and diesel oil used per mile throughout the area on control operations. Actually, however, drifts sprayed with creosote and water averaged 62.38 inches wide and 9.7 inches deep, while the general average on all other treated beaches was 31.3 inches wide by 7.6 inches deep. On equal quantities of grass it appears that the amount of creosote and water required for treatment need not exceed the rate of application for the mixture of creosote and oil formerly employed.

A daily record of the different tests conducted with the creosote-water emulsion is given in table 2. The yards of grass treated and the average width and average depth are estimates made each day by a foreman of each spray unit who was experienced in entomological control work. The rate of application varied considerably with the compactness and depth of the grass, and to some extent with different nozzlemen who applied the spray. If allowance is made for the differences in quantities of grass encountered in the various areas, it appears that the average rate of application per mile for each spray unit was somewhat uniform.

PENETRATION AND DURATION OF CREOSOTE IN TREATED BAY GRASS.—Repeated examinations of treated grass revealed that a good coverage and a good penetration were obtained. Further, no living larvae could be found in the treated areas, whereas dead larvae were often found with ease. In wet, soggy grass rows the penetration of the creosote-water emulsion appeared to be even better than in locations where the creosote-Diesel oil mixture was used. The latter appeared to have more of a tendency to form a film on the surface of the wet grass blades, whereas the water mixture appeared to unite better with the water on the grass.

In addition to observations made on treated grass at different places in the entire area where tests were conducted, specific stations were set up for detail studies. The following is representative of observations made on the different tests:

Table 2.—Summary of spray tests with creosote-bay water emulsion.

DATE	MATERIAL USED, GALLONS	SHORE LINE COVERED, MILES	GRASS TREATED, YARDS	SHORE LINE TREATED, PER CENT	APPROXIMATE AVERAGE WIDTH OF GRASS, INCHES	APPROXIMATE AVERAGE DEPTH OF GRASS, INCHES	MATERIAL PER MILE OF GRASS, GALLONS
Sept. 22	800	1.0	1,428	81.1	48	6	958.9
23	800	1.5	1,932	73.1	24	4	728.7
24	800	1.0	1,341	76.1	60	8	1,049.9
25	900	.75	986	74.6	78	10	1,606.4
26	1,000	.5	821	93.2	108	24	2,143.7
27	600	.25	416	94.5	96	18	2,538.4
29	1,200	1.0	1,310	74.4	120	20	1,612.2
30	1,600	1.0	1,291	73.3	140	24	2,181.2
Oct. 1	1,400	2.0	2,521	71.6	120	18	977.3
2	2,800	12.25	4,610	21.3	34	6	1,068.9
3	1,750	21.0	2,450	66.2	42	12	1,257.1
4	1,000	1.0	1,120	63.6	60	8	1,571.4
6	1,500	1.0	1,243	70.6	72	10	2,123.8
13	400	.6	900	85.2	24	6	782.2
14	200	.25	400	90.9	36	4	880.0
15	400	.50	800	90.9	37	4	880.0
16	200	.25	200	45.4	30	6	1,760.0
18	400	1.0	1,000	56.8	16	4	704.0
Average	986.1	2.60	1,376	30.0	62.38	9.7	1,261.5
Total	17,750	46.85	24,769 (=14.07 miles)				

Material: Creosote 1 part and bay water 3 parts.
Quantity used: 200 gallons.
Length of tide drift: One-half mile
Average width of grass: 48 inches
Average depth of grass: 6 inches
Date of treatment: September 22, 1941

Results: Good coverage and penetration were obtained at the time of treatment. On September 23 an examination revealed many dead larvae and no live ones. Two days after treatment hard rains had little effect on the treated grass. Subsequent to treatment a new drift of green grass was deposited just below and, in some places, contiguous to or upon the treated grass. The new material appeared to receive sufficient creosote from the treated material to prevent breeding, because on September 30 it was not infested, while grass deposited several feet from the treated area contained many eggs and larvae. This treated plot was examined daily until October 22, and at that time the grass was still coated with creosote and supported no breeding.

According to numerous observations made over the entire treated area, grass once treated with creosote will not subsequently breed dog flies. This was substantiated. On East Bay, where there was a heavy deposit of *Thalassia testudinum* about a mile in length, the regular creosote-water emulsion was applied on October 16. When examined on November 15, the grass was still well treated, but in a dehydrated state. If all the creosote had been removed after such a long period, the grass would have been too dry to permit breeding of dog flies. More rigid tests were made on the effect of tidal action on the removal of creosote. In one of these, 4 cubic feet of heavily infested bay grass (*Thalassia testudinum* and *Cymodocea manatorum*) was sprayed in the usual manner with a mixture of 1 part of creosote oil to 3 parts of water on September 22. The grass was immediately caged where it was subjected to constant tidal washing except during the lowest tides. When examined each day it was found that sufficient creosote oil was present until October 1, at which time the cage was destroyed by rough tides.

In another test 4 cubic feet of green grass (*Thalassia testudinum* and *Cymodocea manatorum*) was placed in a 6 by 6 foot wire cage, fastened below high-tide mark, and sprayed with the creosote-water emulsion on September 25. The grass was inundated within 5 hours after treatment and was subjected to a daily washing by the tides for a period of 10 days. At the end of that time the grass was still impregnated with creosote. Half the grass from this cage was removed after 5 days exposure to tidal action and was placed on high ground for a possible infestation. The daily examinations made upon it for 5 days showed that no infestation occurred, whereas a pile of untreated grass used as a check beside the treated

material became infested with both larvae and eggs before October 7.

These tests, together with the extensive and intensive observations made on 14 miles of the treated grass, demonstrated beyond doubt the ability of creosote oil to remain in treated grass regardless of tidal action.

MORTALITY OF IMMATURE STAGES IN TREATED GRASS.—Intensive examinations made over approximately 10 miles of well-infested grass that had been treated with creosote-water emulsion failed to reveal any living larvae, although it was a common occurrence to find dead larvae.

On September 22 a screened cage 6 feet square and 3 feet high was erected over 16 cubic feet of grass in a tide drift that had been sprayed in the usual manner with the creosote-water emulsion. Each day until October 7 observations were made and no flies emerged from the treated grass. A cage erected over an equal quantity of untreated grass adjacent to the treated plot and used as a check produced 390 adult dog flies by October 7, at which time both cages were destroyed by a hurricane. This test not only demonstrated the effectiveness of the insecticide, but indicated that a heavy population of dog flies would have been present if no treatment had been made.

Observations made constantly on large quantities of treated but uninfested green grass showed that it never became infested.

The mortality of pupae in bay grass well treated with creosote is susbtantially 100 per cent (Dove & Simmons 1942).

In view of these observations, it is concluded that in actual practice the use of creosote-water emulsion in proportions of 1 to 3 is effective in destroying the immature stages of the dog fly.

ADVANTAGES OF THE CREOSOTE-WATER EMULSION.—The principal advantage in using water as a diluent for creosote instead of oil is the savings incurred. During September and October 1941, 143,975 gallons of diesel oil was used in control work as a carrier for the creosote. The elimination of this item would result in a net saving of about $9500. In addition, the spray units frequently operated where they were inaccessible to trucks so it was necessary to supply them with oil from a boat. Not only was this expensive, but it sometimes caused serious delays in operation. It is estimated that the reduction in cost for transportation by truck tanks and barge tanks, and elimination of delay due to such transportation, would add an additional 50 per cent to the above savings. The water may be obtained through a filler hose from the bay beneath the barge. The spray unit, therefore, would only have to maintain a supply of creosote, and one small auxiliary supply barge could transport enough for use during an entire week's operation. By eliminating the cost of oil, reducing the costs for transportation and speeding up the spray operations, it is estimated that the saving should amount to at least $15,000 on a program for dog fly control extending from Pensacola to Apalachicola, Fla.

SUMMARY.—Tests with 17,750 gallons of material on 14.07 miles of grass tide drifts have shown that a mechanically prepared creosote-water emulsion can be used successfully and economically in treating bay grass for control of breeding of the stablefly, or "dog fly," *Stomoxys calcitrans* (L.).

Bay grass treated with creosote and bay water remains treated for 1 month, and grass once well treated does not subsequently breed any dog flies. By eliminating the cost of diesel oil, by reducing transportation costs, and by speeding up spray operations, at least $15,000 can be saved by the use of the creosote-water emulsion instead of creosote and diesel oil solution for a dog fly control program extending from Pensacola to Apalachicola, Fla.—2-21-42.

LITERATURE CITED

Dove, W. E., and S. W. Simmons. 1942. Control of the stablefly or "dog fly," breeding in shore deposits of bay grasses. JOUR. ECON. ENT. **35**(4):

Simmons, S. W., and W. E. Dove. 1941a. Breeding places of the stablefly or "dog fly," *Stomoxys calcitrans* (L.), in northwestern Florida. JOUR. ECON. ENT. **34**(3): 457–62.

Simmons, S. W., and W. E. Dove. 1941b. Control of dog fly breeding in beach deposits of marine grasses. U. S. Dept. Agr., Bur. Ent. and Plant Quar. Circ. **E-541.**

SCIENTIFIC NOTES

Notes on the Biology of *Microbracon hebetor*

AUSTIN W. MORRILL JR., *U. S. Department of Agriculture, Bureau of Entomology and Plant Quarantine*

The observations on which this report is based were made in the San Joaquin Valley, Calif., where the principal host of *Microbracon hebetor* (Say) is the larva of the raisin moth, *Ephestia figulilella* Greg. Infestation of dried fruits by the raisin moth begins on ranches, and there the parasite kills some larvae in hibernation quarters in soil and under the bark of grapevines as well as full-grown larvae migrating from infested fruit. In storages, where thousands of tons of raisins and other dried fruits are concentrated, the small, dark, wasplike insects sometimes become very numerous, stinging and parasitizing migrating larvae, and under such conditions the limp bodies of the victims may be present in large numbers. It is obvious from casual observations that parasitization by *Microbracon* affects the development of the raisin moth and the Indian-meal moth, *Plodia interpunctella* (Hbn.,) but the economic importance of the control exerted has not been determined.

To obtain data on the life history of the parasite, adults were brought to the laboratory in January, were allowed to mate, and the pairs were placed in glass vials 1 inch in diameter by 4 inches in depth. One living, full-grown larva of the raisin moth or Indian-meal moth was placed with each pair. Each day the parasites were examined, transferred to another vial, and given a fresh larva. The raisin moth usually was provided, because of its greater abundance, but the female parasites showed no preference for either species. The laboratory was warmed during the day in winter and occasionally in early spring. Rearings were continued for about 1 year. Fourteen generations (egg-to-adult developments) were produced by use of the females that emerged earliest from each brood of eggs (Tables 1 and 2).

From 1 to 11 opaque, white eggs were deposited beneath or beside each paralyzed larva, the mean number being approximately 5. From 2 to 358 eggs were laid per female, the average being about 90.

The nearly transparent, newly hatched larvae attached their mouth parts to the host within a few hours after hatching, sometimes crawling 4 or 5 mm., and usually began feeding at once. As growth progressed they changed in color to pinkish of opaque white. Larvae that hatched in March fed for about 6 days and spent the same time in white cocoons near the shriveled, dark-colored remains of the host larva. The larval periods shown in table 1 include the time spent in feeding and in preparing for pupation. Pupation required about as long as the entire larval period. Emergence from the cocoons usually did not occur for several days after transformation to the adult had been completed.

The females began to sting host larvae soon after emergence, usually within an hour, and mating ordinarily followed emergence after the same interval. Unfertilized females produced males only.

Twenty-eight females which emerged in March and April lived from 5 to 62 days, the average being 33 days. Twenty males which emerged during the same months lived from 4 to 22 days, the average being 10 days. The longer life of the females may be accounted for by their habit of feeding at points where their sting penetrates the skin of the host larva. Males were not seen to take food, except occasionally when they came upon the exudate at a freshly made puncture.

Females paralyzed many more larvae than were needed for oviposition purposes. It was a common occurrence for females to lay eggs on larvae paralyzed by other females. Some of them deposited eggs without having fed on host larvae, and some fed without ovipositing thereafter.

The preoviposition interval of 28 females observed in March and April was from 1 to 23 days, the average being 4 days. The oviposition periods ranged from 1 to 55 days and averaged 26 days. Deposition of eggs was irregular, periods of several days often

Table 1.—Length of metamorphic periods of 14 generations of *Microbracon hebetor* reared in the laboratory at Fresno, Calif.

Generation No.	Females	Period of First Egg to Last Emergence	Average Incubation Period	Average Larval Period	Average Pupal Period	Average Egg-to-Adult Period	Average Mean Temperature
	Number		*Days*	*Days*	*Days*	*Days*	*°F*
1	1	Jan. 31–Mar. 13	3.6	11.5	13.2	28.3	65.2
2	11	Mar. 4–Apr. 20	3.7	11.7	12.8	25.1	68.2
3	10	Apr. 1–May 3	2.7	9.1	8.8	20.6	69.5
4	6	Apr. 24–June 2	3.2	9.8	8.6	21.8	70.0
5	5	May 20–June 9	1.6	7.2	5.3	14.1	75.9
6	3	June 6–June 23	1.1	5.5	6.0	12.6	78.2
7	2	June 24–July 25	1.1	5.6	3.5	10.2	85.8
8	2	July 10–Aug. 1	1.06	4.4	4.0	9.5	86.1
9	1	July 24–Aug. 9	1.57	4.7	3.7	10.0	83.9
10	1	Aug. 8–Aug. 23	1.0	6.0	4.3	11.3	84.1
11	1	Aug. 21–Sept. 5	1.0	5.5	3.6	10.1	83.5
12	1	Sept. 6–Sept. 22	1.8	8.0	7.0	16.8	81.4
13	1	Sept. 29–Nov. 13	3.8	10.1	13.0	26.9	66.0
14	1	Nov. 10–Jan. 21	3.6	15.3	11.8	30.7	60.4

Table 2.—Proportion of *Microbracon hebetor* individuals of 14 generations completing various metamorphic periods from egg to adult in the laboratory at Fresno, Calif.

Generation No.	Females	Average Eggs Laid per Female	Eggs Incubated	Eggs Hatching	Larvae Pupating	Adults Emerging	Females Emerging	Pupae Producing Adults	Eggs Producing Adults	Average Mean Temperature
	Number	*Number*	*Number*	*Per Cent*	*Per Cent*	*Number*	*Per Cent*	*Per Cent*	*Per Cent*	°*F.*
1	1	90	90	81.1	100.0	71	32.4	97.3	78.9	65.2
2	11	123.7	591	64.3	61.8	209	71.3	88.9	35.4	68.2
3	10	114.6	638	77.9	51.9	190	40.5	73.6	29.8	69.5
4	6	120.6	464	59.9	46.8	115	60.8	88.5	24.8	70.0
5	5	90.4	435	58.4	54.3	130	45.3	94.2	29.9	75.9
6	3	26.6	80	38.8	48.4	11	72.7	73.3	12.5	78.2
7	2	177.5	355	56.3	67.0	114	64.0	85.1	32.1	85.8
8	2	81.5	141	61.7	62.1	53	56.6	98.1	37.6	86.1
9	1	71	71	53.5	68.4	19	52.6	73.1	26.8	83.9
10	1	44	44	61.4	55.6	8	50.0	53.3	18.2	84.1
11	1	42	42	59.5	88.0	19	47.3	86.4	45.2	83.5
12	1	55	55	87.3	39.6	11	18.1	57.9	20.0	81.4
13	1	115	115	54.8	74.6	24	66.6	51.1	20.9	66.0
14	1	153	100	52.0	76.9	40	50.0	100.0	40.0	60.4

intervening between layings. The post-oviposition life was from 0 to 44 days, with an average of 5 days.

Observations made in raisin storages during the winter showed that nearly all the parasites present were females. Since unfertilized females produce only male progeny, the proportion of males increased rapidly in the spring. In summer the sexes were present in about equal numbers.—6-10-42.

Effect of Insecticidal Drift in Small Plots upon Boll Weevil and Cotton Aphid

G. L. SMITH, A. L. SCALES, and J. A. FONTENOT,
U. S. Department of Agriculture, Bureau of Entomology and Plant Quarantine

In recent years there has been a tendency to reduce the size of plots in field experiments conducted by the Bureau of Entomology and plant quarantine, of the United States Department of Agriculture, for comparing insecticides against cotton insects. Since questions have arisen concerning the effect of insecticidal drift from small plots to adjacent plots, experiments were conducted at Tallulah, La., in 1941 to obtain information on this subject.

METHODS.—Small field plots were arranged so that check plots adjoined the treated plots on two sides or on all sides (Fig. 1). Each plot was 10 rows, or 35 feet, in width by 97 feet in length and one-thirteenth acre in area. All insect records were made on 1/20-acre areas near the center of the plots.

The treatments used were calcium arsenate, calcium arsenate to which sufficient derris had been added to make 0.5 per cent of rotenone in the mixture, and a special calcium arsenate thought to contain a high percentage of water-soluble arsenic pentoxide. Analysis finally showed, however, that the special calcium arsenate contained only 8.7 per cent of water-soluble arsenic pentoxide and the standard material contained 8.4 per cent.

Seven applications of each treatment were made with single-nozzle rotary guns at daybreak during the period July 18 to August 18. All applications were made at 5-day intervals except the second, which was made on the sixth day on account of rain. There were numerous showers during the dusting period, but no rains heavy enough to make redusting necessary fell within 24 hours after the applications. On the same dates the treatments were applied with a small plunger-type dust gun to individual plants in the laboratory yard.

The quantities of insecticides applied per acre in the field plots are shown in figure 1. The dosages used on plants in the laboratory yard were probably heavier, but were more uniform than those in the field plots.

Immediately after each application a screen cage was placed over a single cotton plant near the center of the first, third, and fifth rows of each plot, includ-

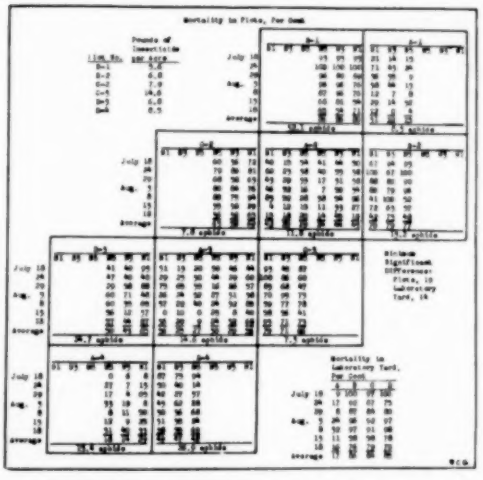

FIG. 1.—Boll weevil mortalities in field plots and in the laboratory yard after the following treatments: A, Check; B, standard calcium arsenate; C, standard calcium arsenate and derris; and D, special calcium arsenate. Plot arrangement and aphid populations per square inch of leaf surface are shown. Weevil mortality counts were taken on the first, third, and fifth rows from the north and south ends of 10-row plots.

ing the checks. Similar cages were placed over treated plants in the laboratory yard and over untreated plants sufficiently removed that any effects from drifting would be avoided. Boll weevils were released in all the cages, and mortality was determined by a method previously described (Smith and Scales 1937*c*.

Aphid populations were determined in each plot, including checks, before treatments began and thereafter at weekly intervals by counting the aphids per square inch on the fourth leaf from the top on 50 plants near the center of the plots. Only the counts made after treatments began are included in the averages.

RESULTS.—Boll weevil mortalities are presented in fig. 1. Mortalities in the first row of the checks adjacent to the treated plots were in most cases higher than on the third and fifth rows. The check plots having a treated plot adjacent on two sides had an average weevil mortality of 22.7 and 20.3 per cent as compared with average mortalities of 35.1 and 33.8 per cent in the check plots having treated plots on all sides. In the laboratory yard where the check cages were not near treated plants the average mortality was only 17 per cent. The average mortality was 79.6 per cent in the two plots treated with the standard calcium arsenate, 67.6 per cent in the two plots treated with the mixture of standard calcium arsenate and derris, and 50.3 per cent in the two plots treated with the special calcium arsenate. In the laboratory yard the average mortalities for the three treatments were 86, 84, and 85 per cent, respectively.

The cotton aphid infestation in all plots in this experiment was 0.5, or less, aphid per square inch before treatments were begun. The average number of aphids found in each plot after treatments started (Fig. 1) averaged 12.5 per square inch in the four check plots, 22.7 in the two plots dusted with standard calcium arsenate, 7.6 in the two plots dusted with the mixture of a standard calcium arsenate and derris, and 25.8 in the two plots dusted with the special calcium arsenate.—2-10-42.

LITERATURE CITED

Smith, G. L., and A. L. Scales. 1937. Toxicity of a number of insecticides to three cotton insects. JOUR. ECON. ENT. 30(6): 864–9.

An Amphipod Household Pest in California

ARNOLD MALLIS, *University of California, Los Angeles*

A number of householders from various parts of Los Angeles County have been startled by the appearance of small red shrimp-like animals (Fig. 1) in their homes. These are always dead, and thus are a nuisance merely because of their presence. This amphipod is related to the beach flea, and was classified by C. R. Shoemaker of the Smithsonian Institution as *Talitrus sylvaticus* Haswell. According to Dr. Shoemaker, "This species was first taken in California in 1918 and has been taken there several times since. It is probable that it has been observed on many occasions which have not been recorded. The species was first described from New South Wales and afterwards reported from several of the Pacific Islands, including Hawaii, and in 1918 it was first observed in California, which constituted the first record for the Western Hemisphere. It has since been taken also in Louisiana."

The late W. F. Smith first brought these amphipods to the attention of the writer in 1938. They had entered a house in Wilmar, California, during a rainy period, and were apparently coming from some piles of leaves in the yard. In 1940 D. Hall, a pest control operator, found them sufficiently plentiful in

FIG. 1.—*Talitrus sylvaticus* Haswell.

the attic of a house in Hollywood so as to be swept up in handfuls. They were collected about a week after a rain. This pest control operator reported them again, in 1941, from leaves under the shrubbery of another home in Hollywood.

During the month of January, 1941, an infestation of *Talitrus sylvaticus* Haswell occurred in a home in West Los Angeles. Their conspicuous red bodies were found in great numbers in the basement and garage. The amphipods entered the basement through windows screened with $\frac{3}{8}$" mesh. Further investigation showed them to be present under ivy used as a lawn covering. Naturally, the soil beneath the ivy was very moist. The living amphipods were brownish-black in color, and covered with a moist film. They jumped about like fleas, and were captured only with great difficulty. The amphipods were present in the soil to a depth of a half inch.

Since then three other infestations have come to the attention of the writer, one on the campus of the University of California at Los Angeles, another in Santa Monica, and the last in San Gabriel. In the latter locality, a part of the grounds was covered with ivy, and it was beneath this ivy that the living amphipods were found.

It is very likely that rain and excess moisture forces these animals to seek a somewhat drier situation. They then invade the house by jumping through windows, or crawling over thresholds, and here they die because of insufficient moisture, their dark-brown bodies turning shrimp red. Ivy, as a ground cover, and leaf mold beneath shrubbery, apparently offer a suitable habitat for these moisture-loving animals. The entry of this amphipod into the home is a rare occurrence, and on no occasion has it been necessary to resort to control methods after the initial complaint.—5-19-42.

Notes on the Effect of Arsenicals upon the Cotton Aphid, Predators, and Other Insects

G. L. SMITH and J. A. FONTENOT,
U. S. Department of Agriculture, Bureau of Entomology and Plant Quarantine

Boll weevils used in cage experiments at Tallulah, La., are collected from nearby fields that have not been treated with insecticides by shaking cotton plants over a bag held open at one end by a barrel hoop. During the 1941 season there were few fields in the vicinity of Tallulah that were not dusted for weevil control. In the untreated fields it was noticed that few cotton aphids were present and that large numbers of coccinellid adults and larvae were collected with the weevils, while in most of the dusted fields large numbers of aphids and few coccinellid adults or larvae were present after July 1.

METHODS.—Arrangements were made to apply arsenical dusts in parts of three fields located several miles apart and to leave parts of the fields untreated in which to collect weevils for the cage experiments. Field A contained about 4 acres and, although several other small fields were nearby, the nearest dusted field was at least half a mile distant. Fields B and C were near dusted fields that had severe aphid infestations when the tests were begun. Examinations were made from each field before dusting was started to determine the initial populations of aphids, coccinellid larvae and adults, chrysopid larvae, mirids, *Microbracon* sp., and boll weevils, and thereafter at weekly intervals during the experimental period of 4 to 5 weeks. The populations of aphids were determined by counting the aphids per square inch of leaf surface near the top of 50 plants and of the other insects by shaking 100 plants at each of two points in the dusted and undusted areas of each field.

Field A received five effective applications of a mixture of scrap samples of calcium arsenate and about 10 per cent of paris green during the period July 23 to August 18. All applications were made about 6 p.m. with a single-nozzle rotary-type hand dust gun. Field B received three effective applications of a mixture of 3 parts of a heavy calcium arsenate containing a high percentage of water-soluble arsenic pentoxide and 1 part of clay between August 5 and 16. The first two applications were made with a power-type five-nozzle machine and the last with rotary-type hand dust guns. Field C received four effective applications of a mixture of calcium arsenate and 1 per cent of free nicotine between August 4 and 18. These applications were all made with a rotary-type hand dust gun late in the afternoon.

RESULTS.—The numbers of insects found in the dusted and undusted portions of the fields are shown in table 1. The aphid population at the conclusion of the experiment was three times as great in the dusted as in the undusted portion in field A, four times as great in field B, but only slightly greater in field C, where nicotine had been added to the calcium arsenate. Field C was a small field of late cotton adjacent to fields of older cotton that had been dusted with calcium arsenate from early June to August. The aphids had become sufficiently abundant in the older cotton to cover the plants with honey-dew and to cause shedding of foliage before August 1.

Considerably fewer coccinellids and chrysopid larvae but more boll weevils, were taken in the dusted than in the undusted areas. Although there was a reduction of both coccinellid adults and larvae in the treated portions of all fields, the reduction of larvae was greater than that of adults. The reduction of mirids that occurred in field A could have been due to natural migration, but was more likely caused by the paris green, as previous tests have shown that paris green is more toxic against the mirids (especially the tarnished plant bug) than calcium arsenate. The numbers of *Microbracon* adults taken were too small to permit any conclusions to be drawn on the effects of the arsenicals on these parasites. The greater number of boll weevils taken in the dusted portions of all fields was probably due to weevils moving into the plots in search of food. The dense populations of weevils in the undusted areas during August destroyed most of the food, whereas there was an increase of squares and blooms in the dusted areas during the early part of the experimental period. Some of the weevil reduction in the untreated areas was perhaps due to the collecting of them for experimental purposes.—2-11-42.

Table 1.—Insect populations on cotton following dusting with different insecticide mixtures and on undusted cotton.

Insect	Field A		Field B		Field C	
	Undusted	Calcium Arsenate—Paris Green	Undusted	Calcium Arsenate—Clay	Undusted	Calcium Arsenate—Nicotine
	Number of insects per square inch of leaf area					
Aphids	6.31	20.79	6.27	28.57	0.73	1.20
	Number of insects per 1,000 plants					
Coccinellids:						
Adults	131	38	160	44	122	67
Larvae	61	6	60	5	33	3
Chrysopid larvae	25	4	14	9	15	22
Mirids:						
Adults	53	20	56	80	167	73
Nymphs	41	8	74	68	182	234
Microbracon sp.	9	5	1	3	0	0
Boll weevils	628	770	661	796	1,433	1,588

Methods of Rearing the Pink Bollworm Parasites *Chelonus* and *Microbracon*

L. W. NOBLE and W. T. HUNT,
U. S. Department of Agriculture, Bureau of Entomology and Plant Quarantine

Breeding introduced parasites of the pink bollworm, *Pectinophora gossypiella* (Saund.), was begun at Presidio, Tex., in 1932. Progress was retarded by a number of factors pertaining to host material and rearing methods. Some of the larval parasites required continuous breeding and a supply of host larvae at all times, but sufficient pink bollworms could be collected in the field by practical methods for only a short period. Although resting-stage pink bollworms in cotton seed or collected from gin trash could be stored over winter, these invariably became infested with mites, and their destruction in the spring was necessary. Also, parasite stocks were sometimes reduced or lost because of the mite infestation introduced into the breeding room from this source. Rearing pink bollworms in the laboratory was impractical because of the enormous amount of labor required and the short season when cotton was available for food.

With the view of overcoming at least part of these difficulties, studies made of other possible hosts resulted in the selection of the Mediterranean flour moth, *Ephestia kuehniella* Zell., as a substitute host. This host has been used since 1935 for rearing *Microbracon* and *Chelonus* parasites of the pink bollworm with outstanding results for the latter genus. The use of this insect as a parasite host, together with certain changes in breeding technique, has resulted in development of improved methods of rearing pink bollworm parasites which are adaptable to other similar projects.

The Mediterranean flour moth as a laboratory host for breeding *Microbracon* and *Chelonus* parasites has many advantages. Most species of these genera develop upon it. The ease with which the flour moth can be reared insures an adequate host supply at all times at low cost. Since it develops on dry food, simple sanitary measures prevent disease. Although it is attacked by mites, this does not prohibit a satisfactory breeding program, because unit-production methods insure against loss of the entire stock, and new mite-free cultures can be started.

The Mediterranean flour moth is far superior to and has entirely replaced the pink bollworm as host in the rearing of *Chelonus blackburni* Cam. and *C. pectinophorae* Cush. during all seasons. These species oviposit in the host egg and complete development in the host larva. Other than handling the adult parasites and exposing the host eggs to them, rearing these parasites amounts simply to rearing their hosts. The method used for rearing the flour moth is described by Mansbridge (1933). The flour moth eggs are obtained in large numbers by adaptation of methods developed by Flanders (1930) and Spencer *et al.* (1935). The eggs are then scattered over a disk of moist absorbent-paper toweling pressed into a petri dish and exposed to the parasites in a cloth-covered oviposition cage. They adhere to the paper after drying, and, although many are later dislodged by the parasites, the females continue to oviposit. After 24 hours' exposure the paper containing the eggs is removed and placed in a can with food for development of the larvae.

The Mediterranean flour moth is not so satisfactory as the pink bollworm for the *Microbracon* parasites, but has been used with some degree of success for rearing *M. kirkpatricki* Wilk., *M. nigrorufum* Cush., and *M. mellitor* Say when pink bollworms were not available. In the breeding methods employed, decay is more prevalent and the percentage of parasite development is lower on the Mediterranean flour moth than on the pink bollworm larvae. In their early breeding of *Microbracon* the writers used methods developed by other workers. Since most species of this genus do not attack hosts openly exposed, it is necessary to enclose the larvae in some kind of covering which the females can pierce before they will oviposit. Mohammed Kamal reared *M. kirkpatricki* on the pink bollworm in Egypt by placing the host larvae in perforated wheat straws to induce oviposition. Since this procedure was too laborious for large-scale rearings, the writers found that a more satisfactory method was to permit the female parasite to insert its ovipositor through a cloth. The hosts were first paralyzed by immersing the larvae in hot water, as described by Baker & Jones (1934). Paralysis of the pink bollworm larvae is produced by immersion in water at 120° F. for 7 minutes. Mediterranean flour moth larvae require immersion for only 1 minute at 116° F. The latter larvae are killed by longer periods of immersion or by higher temperatures and consequently decay before the parasites have time to complete their development.

Owing to later improvements in the method of exposing host larvae to the female parasites (Noble & Hunt 1937), the necessity for artificial paralysis is avoided and the danger of decay reduced. The normal live larvae are confined between a heavy paper and a loosely woven cloth bound in an embroidery hoop. This method saves a great deal of labor over the wheat-straw method and also has advantages in controlling mite infestation. All the parasite larvae attach their cocoons to the paper disk, which is removed from the embroidery hoop as soon as the cocoons are formed. The remains of the host larvae are removed from the paper at this time, and, the mites are therefore deprived of food and the danger of an infestation building up is reduced.—2-23-42.

LITERATURE CITED

Baker, W. A., and L. G. Jones. 1934. Studies of *Exeristes roborator* (Fab.), a parasite of the European corn borer, in the Lake Erie area. U. S. Dept. Agr. Tech. Bul. **460.**

Flanders, Stanley E. 1930. Mass production of egg parasites of the genus *Trichogramma.* Hilgardia **4**(16): [465]–501.

Mansbridge, G. H. 1933. The breeding of *Ephestia kühniella* Zl. in large numbers for experimental work. Ann. Appl. Biol. **20** (4): 771–4.

Noble, L. W., and W. T. Hunt. 1937. Method of rearing *Microbracon kirkpatricki* Wilk. and *Microbracon mellitor* Say. U. S. Dept. Agr., Bur. Ent. and Plant Quar. ET-99.

Spencer, Herbert, Luther Brown, and Arthur M. Phillips. 1935. New equipment for obtaining host material for the mass production of *Trichogramma minutum,* an egg parasite of various insect pests. U. S. Dept. Agr. Circ. **376.**

Notes on the Control of Cotton Aphids

G. L. SMITH, A. L. SCALES, and J. A. FONTENOT,
U. S. Department of Agriculture, Bureau of Entomology and Plant Quarantine

During the 1941 season infestations of the cotton aphid, *Aphis gossypii* Glov., were generally severe in the vicinity of Tallulah, La., and in most of the Louisiana-Mississippi Delta. Boll weevils were also abundant in this area, and the prolonged dusting programs necessary for weevil control were no doubt responsible for the very general aphid infestation. Several preliminary experiments were inaugurated to study nicotine sulfate and free nicotine in different concentrations and with several carriers as aphid controls. It is recognized that the results are insufficient to be conclusive, but some of the data may furnish leads for further investigations.

Dust mixtures of nicotine sulfate, with calcium arsenate, lime, or tobacco dust as a carrier, and free nicotine, with calcium arsenate, lime, clay, or tobacco dust, were used. The dusts were made by thoroughly mixing the necessary quantities of 40-per cent nicotine sulfate solution or 10-per cent free nicotine dust with the carrier to make either 2-per cent or 3-per cent nicotine by weight in the final mixtures. The 40-per cent nicotine sulfate solution was a heavy liquid, whereas the 10-per cent free nicotine dust was a finely ground dust having good dusting qualities without the addition of a diluent.

The first tests were made in a large field near the laboratory that had developed an injurious aphid infestation following dusting with calcium arsenate during July and August. The plots were 20 rows wide and approximately 0.66 acre in area.

Dust applications of the 3-per cent nicotine mixtures, prepared from nicotine sulfate with lime and free nicotine with lime, clay, and tobacco dust, were made on July 30 about 6 p.m. Counts of aphids on 100 square inches of leaf area were made before the applications, to determine the initial infestation, and again on the second and eighth days after dusting, to determine the rate of reduction of the aphids. A reduction of about 66 per cent had occurred by the eighth day in all dusted plots except that treated with the mixture of free nicotine and lime. The very light dosage of about 4.5 pounds per acre in this plot was no doubt responsible for the poor reduction. The poundage in all plots was also a little light for maximum effect from nicotine. Counts in the untreated check plot were made only 10 rows distant from a dusted plot, and the reduction in aphids in the check by the drifting of the dust was about the same as in the dusted plots.

Counts made in these plots on August 13 showed that a considerable aphid infestation was still present, and a second application of each of the mixtures was made in the late afternoon of August 15. The poundage applied was considerably heavier than in the first test, and counts made 3 and 6 days later showed much greater reductions in aphids. In the check plot counts were made 10 and 30 rows from the nicotine-treated plots, and, as in the first test, considerable reduction of aphids was noted on the tenth row, but counts on the thirtieth row showed no reduction of aphids from the nicotine.

The second test with the same 3-per cent nicotine mixtures was made in another field in which a severe aphid infestation developed following three applications of calcium arsenate containing a high percentage of water-soluble arsenic pentoxide. The treated plots were 30 rows wide and approximately 1 acre in area. Only 10 rows were available for the check plot. The applications were made just before dark on August 20, when the atmospheric conditions were considered ideal for dusting. From counts made the second day after treatment, splendid reductions of aphids were obtained in the plots dusted with the mixtures containing free nicotine, but in the plot treated with the mixture of nicotine sulfate and lime the reduction was not so good. This again was no doubt due to the light application of only 6.75 pounds per acre as compared with 13.5 to 15 pounds per acre of the free nicotine mixtures. In the check plots counts were made within 10 rows of the treated plots, and a large reduction of aphids occurred.

A third test was made in a 25-acre field that had developed a severe aphid infestation. A portion of the field had been used for small-plot experiments and the remainder dusted by the owner with calcium arsenate for boll weevil control. In the small plots the last application was made on August 18 and in the rest of the field during the night of August 22. The residues from several barrels of mixtures of lime and 3-per cent nicotine sulfate were used to dust a large portion of this field beginning in the late afternoon and continuing until after dark on August 22. Five rotary-type hand dust guns with two nozzles were used to make the applications and two rows were dusted with each gun for each trip. Counts made on the third day after dusting showed almost complete aphid control. Counts made in the untreated areas on the south and north side of the field indicated that drift of the insecticide caused considerable reduction of the initial aphid infestation to the south of the dusted area. The aphicide was more effective in the area dusted after dark, when dew was forming, than in the area dusted earlier in the evening, when the air was lighter and there was more drift.

Further tests were made in small plots comparing 2- and 3-per cent nicotine concentrations with several carriers. Nicotine sulfate, with calcium arsenate, lime, and tobacco dust, and free nicotine, with calcium arsenate, lime, clay, and tobacco dust, were used. The plots were arranged in a field 240 rows wide and 140 yards long. Each plot contained 4 rows, or slightly less than 0.125 acre, and buffer areas of 14 rows, or 49 feet, were left between plots. The aphicides were applied with a 2-nozzle rotary-type hand dust gun, one nozzle to each row. The average aphid infestation in this field, as determined by counts made at 6 points the day before the nicotine was applied, was 43.8 per square inch of leaf area. Applications of the aphicides were made on August 27. The 2-per cent concentrations of nicotine sulfate and free nicotine were applied from 6:30 to 6:40 p.m., when there was a light breeze and sharp drift from plot to plot. The 3-per cent concentrations were applied from 6:50 to 7:00 p.m., when there was no breeze and only a slow drift. Aphid counts were made the second day after dusting, on the top and center leaves of 25 plants at 2 points in each plot. In each case the aphid kill was greater on the center leaves than on the top leaves. This result was to be expected, for when drifting occurred the aphicides remained in the lower parts of the plants longer than in the tops. The 3-per cent nicotine concentrations were a little more effective than the 2-per cent concentrations, but the atmospheric conditions were also a little more favorable when the former were applied. There was little dif-

ference in the effectiveness of the nicotine sulfate and the free nicotine mixtures when used as the same concentrations and with the same carriers.

At the time counts were made in the 4-row dusted plots, similar counts were made in the center of each 14-row buffer between the plots to determine the effect of drift upon the aphids in the buffer areas. The reduction of aphids at the center of the buffer areas was much less than in the treated areas, but there was considerable reduction. While the reduction of aphids was greater on the center leaves than on the top leaves in the dusted plots, the reverse was true in the buffer areas. The mixtures made from the free nicotine dust and the lighter carriers, such as lime and clay, seemed to kill more aphids in the center of the buffer areas than the heavier dusts made from the liquid nicotine sulfate. The buffer areas adjacent to the plots treated with free nicotine in tobacco-dust carrier showed little reduction. The tobacco dust is a heavy material and did not drift so far into the buffers as the other carriers.

Both the 2- and 3-per cent nicotine mixtures were further tested on 8 or 10 plants in short sections of cotton rows. Sufficient distance was left between the plants receiving the different treatments to eliminate any effect from drift. All applications were made with a small plunger-type hand gun about daybreak when the plants were wet with dew. They were made over the period from August 26 to September 6, and usually the air was calm.

Counts of aphids made on the second and fourth days after dusting on 1 square inch of leaf area on 10 leaves near the top and 10 leaves near the center of the plants showed a rather high reduction, ranging from 90 to 97 per cent for the different treatments and averaging 94 per cent. The average reduction for the combined counts on the top and center leaves was 93.6 per cent for the 2-per cent nicotine concentrations and 95.6 per cent for the 3-per cent concentrations.—2-10-42.

Laboratory Tests on the Toxicity of Insecticides to the Strawberry Weevil

H. N. POLLARD and W. A. THOMAS, *U. S. Department of Agriculture, Bureau of Entomology and Plant Quarantine*

The strawberry weevil, *Anthonomus signatus* Say, was first recognized as a pest of the strawberry plant in 1871, and since that time serious outbreaks of the insect have occurred periodically in many sections of the United States and Canada.

The injury caused to the strawberry plant by the weevil is the destruction of the young fruit buds. The female weevil lays her eggs in the bud and then partly severs the bud stems so that most of these later wilt and fall to the ground. It is within the severed bud that the larva reaches maturity. In commercial areas the early fruit is the most valuable and studies have shown that the early buds are most severely attacked by the strawberry weevil. Owing to the importance of this insect in the successful production of strawberries, the Bureau of Entomology and Plant Quarantine of the United States Department of Agriculture has conducted control studies both in the laboratory and in the field. The data presented in this paper were obtained by using overwintered weevils in laboratory tests at Chadbourn, N. C., where strawberries are grown commercially and the strawberry weevil is of considerable importance.

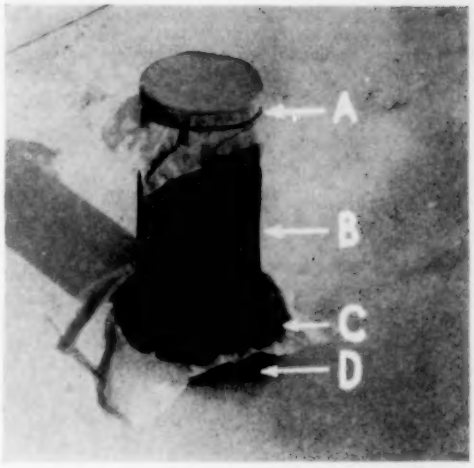

FIG. 1.—Cage assembly used for testing the toxicity of insecticides to the strawberry weevil. *A*, cloth top; *B*, cage; *C*, sand to hold cage in place on cloth collar; and *D*, flowerpot saucer containing moist sand.

METHODS.—Adult weevils were collected from two favored wild host plants, namely, chokeberry, *Aronia* sp., and serviceberry, *Amelanchier* sp., for the laboratory tests. A flower pot saucer was filled with moist sand and a piece of white cloth, called a "collar," was then placed over the sand. One or more of the wild host-plant bud clusters, usually with some opened buds, was transplanted to the saucer. Cotton was carefully packed about the base of the plant where it passed through the collar. A cylindrical 40-mesh copper-screen cage, 10.5 inches high and 4.5 inches in diameter, was placed over the bud cluster and pressed firmly against the collar. Moist sand was packed around the base of the cage in order to hold it firmly in place. Ten active weevils were introduced into the cage, and a cloth, held securely in place by means of a rubber band, was placed over the top. The type of cage used is illustrated in figure 1.

Approximately 3 grams of each insecticide mixture was dusted directly onto the infested host plants. A piece of crimped cardboard was used to help direct the dust as it was blown into the cage. Much of the dust passed through the screen cage, but owing to the fine-mesh wire used, some remained inside. Since these were preliminary tests, no attempt was made to determine accurately the amount of each material remaining in the cage.

Each cage received individual treatment and afterwards was transferred to a labeled shelf in the insectary. In each experiment a single-cage test with 10 weevils was made of each treatment under comparable conditions, and this process was repeated as time allowed until 9 to 12 replicates were completed. Each cage was carefully brushed before being used for another test.

The weevils were exposed to the insecticides for 48 hours, and then the cages were examined for weevil mortality. The active weevils were collected and placed in a shell vial. The difficulty of knowing when to record a weevil as dead was largely overcome by

Table 1.—Mortalities following the different treatments for the strawberry weevil.

TREATMENT	MORTALITY PER CENT
Experiment 1, 1938, 10 replicates	
Undusted check	12
Sulfur	29
Phenothiazine-clay (1 lb.-3 lb.)	37
Domestic synthetic cryolite-sulfur (21% Na_3AlF_6)	70
Domestic synthetic cryolite-clay (21% Na_3AlF_6)	75
Difference required for minimum significance	18
Experiment 2, 1938, 9 replicates	
Undusted check	17
Tobacco dust (0.5% nicotine)	22
Phenothiazine-clay (1 lb.-3 lb.)	23
Calcium arsenate-tobacco dust (1 lb.-5 lb.)	46
Domestic synthetic cryolite-tobacco dust (21% Na_3AlF_6)	49
Difference required for minimum significance	21
Experiment 3, 1939, 12 replicates	
Undusted check	1
Nicotine bentonite (3% nicotine)	2
Calcium arsenate-sulfur (1 lb.-5 lb.)	9
Domestic synthetic cryolite-sulfur (42% Na_3AlF_6)	36
Domestic synthetic cryolite undiluted (83% Na_3AlF_6)	72
Pyrethrin mixture (0.2% total pyrethrins)[1]	96
Difference required for minimum significance	11[2]

[1] A mixture of 1 part of a material coated with an oil solution of the active principles of pyrethrum and 9 parts by weight of pyrophyllite.

[2] Does not apply to comparisons with the check and the nicotine bentonite treatments, as these were not included in the analysis.

the use of a 100-watt bulb and reflector. The weevils that were dead, or feigning death, were picked up individually with a camels-hair brush and brought near the burning bulb. If there was much life present the weevil would invariably wiggle off the brush, or if the insect was moribund its legs could be observed to move. Weevils recorded as dead were kept in labeled, well-ventilated vials for 2 days to determine whether they would recover, but none of them was observed to revive. Although the strawberry weevil is a relatively small insect, measuring only about one-tenth inch in length, 98 per cent of the insects were accounted for in these tests.

In 1938 cryolite with clay and cryolite with sulfur were the most effective mixtures. In 1939 the pyrethrin mixture was the most effective. Undiluted cryolite gave the next highest mortality and was more effective than cryolite diluted with sulfur. Apparently the strawberry weevil was not affected by the nicotine bentonite.

A few tests were conducted in 1938 with new-generation weevils. Some of the same insecticides were used, but the pyrethrin mixture was not tested. The newly emerged weevils did not feed on the dusted plants to any great extent, and consequently it was not possible to determine the most effective material. —6-16-42.

Effect of Sterile and Unsterile Foods on Rate of Development of Wireworms

M. W. STONE, *U. S. Department of Agriculture, Bureau of Entomology and Plant Quarantine*

Considerable difficulty has been experienced by the writer in rearing elaterid larvae in salve cans, especially when large seeds, such as lima beans, are used as food. After these seeds sprouted, their young shoots forced off the lids of the cans, and many of the larvae escaped or became desiccated from the drying out of the soil. To prevent sprouting, the germ of the larger seeds was killed by boiling in water for about 10 minutes.

Since treatment of the seeds appeared to retard the rate of larval development, each of 25 larvae of *Melanotus longulus* Lec. of the 1933 brood was fed one sterile lima bean monthly from the time of hatching, and 75 larvae of the same species and brood were fed moistened, unsterile wheat. Of the first group none pupated within a period of 4 years, and of the second group 32, 29, 8, and 3 per cent pupated 2, 3, 4, and 5 years, respectively, after hatching. The larvae reared on sterile beans developed very slowly and were smaller than those reared on unsterile wheat.

On May 1, 1936, the 17 larvae in the sterile-bean series that were still alive were segregated into 2 groups. Eight of them were continued on the sterile-bean diet, whereas the diet of the other 9 was changed to one unsterile bean monthly. In the latter group, 3 pupations occurred between July 14 and September 1, 1936, and 6 larvae died in 1936–37. In the group continued on sterile beans, 3 individuals died, 1 pupated in 1938, and the remaining 4 died in 1939–40. On October 28, 1936, the remaining larvae in the sterile-bean group averaged 37 mg. in weight and those in the unsterile group 81 mg. In a period of 5 months the larvae that were changed from sterile to fresh limas attained more than double the weight of the other larvae.

To obtain evidence on the relative effect of sterile and unsterile foods on the rate of development of the sugar-beet wire-worm, *Limonius californicus* (Mann.), a series of 600 larvae that had hatched between May 1 and 15, 1937, were divided into 6 lots of 100 each and fed monthly as follows: Group 1, three kernels of corn per larva; group 2, 10 kernels of wheat per larva; and group 3, one lima bean per larva. These foods were soaked in water over night. The larvae in the remaining groups were given the same diet but the food was sterilized by boiling. Freshly sifted soil containing 12 to 14 per cent moisture was used at each feeding, and all groups were confined in the laboratory basement during a period when temperatures ranged from 46° to 88° F. A summary of the mortalities and pupations appears in table 1.

In 1937 fresh lima beans had nearly as many pupations as all other food groups combined. Sterile corn ranked next, followed by unsterile wheat. Fresh limas were also superior on the basis of weight, as weighings made on October 15, 1937, showed that larvae reared on this food averaged 75 mg. as compared with 57 and 47 mg., respectively, for larvae fed sterile corn and fresh wheat. The large mortality during the first year in the sterile wheat and lima-bean groups and the slow growth of the larvae remaining may have been due to the lack of certain vitamins, which had been removed during the boiling process. Hawkins (1936) experienced the same

Table 1.—Effect of sterile and unsterile foods on the development of larvae of the sugar-beet wireworm.

Food	Mortality, Per Cent				Pupation, Per Cent				
	1937	1937	1939–41	Total	1937	1938	1939	1940	Total
Unsterile:									
Corn	19	1	3	23	7	62	7	1	77
Wheat	13	7	1	21	11	60	7	1	79
Lima beans	22	9	7	38	31	23	8	0	62
Sterile:									
Corn	20	12	5	37	12	39	12	0	63
Wheat	44	4	0	48	4	40	7	1	52
Lima beans	66	10	22	98	0	2	0	0	2

difficulty when rearing larvae of *Agriotes mancus* (Say) on sterile potato agar, and he suggested that either the vitamins had been destroyed or the absence of soil bacteria was a factor.

In 1938 unsterile corn and wheat had the greatest numbers of pupations, and on the basis of total pupations for the 4 years 1937–40 unsterile wheat, corn, and lima beans ranked in the order named. Of the group of larvae fed sterile lima beans two individuals completed development in 1938 but the remainder died that year. In the other food groups a few larvae completed development in 1939 and 1940. One larva fed unsterile corn lived until March 1941.

It appears from these data that certain vitamins in lima beans and wheat necessary for the growth of *Melanotus longulus* and *Limonius californicus* larvae were destroyed by the boiling.—4-2-42

LITERATURE CITED

Hawkins, John H. 1936. The bionomics and control of wireworms in Maine. Maine Agr. Expt. Sta., Bul. **381**: 47.

Ambrosia Beetles Attacking Deciduous Fruit Trees in California

E. GORTON LINSLEY and G. F. MACLEOD,
University of California, Berkeley

During the past year two species of ambrosia beetles have been observed in California injuring living deciduous fruit trees. In the summer and fall of 1941, *Pterocyclon dentiger* (Lec.) attacked a large number of Persian walnut trees in Napa County. The adults confined their attacks to the black walnut root stock. They entered the wood at a right angle to the surface and at a depth of two or three inches the galleries branched horizontally and ran through the sapwood. The entrance burrows were conspicuous because of accumulations of boring frass. At the time when the observations were made oviposition had not yet begun, although completed burrows were found in trees which had died during the previous season. Current season trees were also being attacked by the nautical borer, *Xylotrechus nauticus* Mann. The eggs of this species and of its predator, *Temnochila virescens* (Fab.), were very abundant and, like the attacks of the ambrosia beetle, were confined to black walnut root stock. The majority of the affected trees had a healthy appearance although examination revealed that they were suffering from disease. *Pterocyclon dentiger* has been previously reared from oak (Chittenden 1893; Hubbard 1897), and Doane & Gilliland (1929) have recorded a few observations on its habits on this host. We are not aware that it has been previously recorded from walnut.

FIG. 1.—Egg gallery of *Xyloborus* (*Anisandrus*) *dispar* (Fab.) in nectarine wood.

Xyloborus (*Anisandrus*) *dispar* (Fab.), a better known species associated with a wide variety of deciduous trees, was found severely injuring nectarines in Siskiyou County. The attacks were confined to branches and frequently produced a girdling effect. Mote (1935), in commenting on the habits of this species in Oregon, remarks that the beetles are attracted to and attack only devitalized trees which have developed a sour sap condition.

Since available evidence suggests that both of these ambrosia beetles may attack unhealthy trees before conspicuous external evidence appears to indicate the condition of the tree, these species, along with *Xylotrechus nauticus*, may be regarded as symptoms of an altered physiological condition in the trees.—5-29-42.

LITERATURE CITED

Chittenden, F. H. 1893. Biologic notes on some species of Scolytidae. Proc. Ent. Soc. Wash., **2**: 391–5.

Doane, R. W. and O. J. Gilliland. 1929. Three California ambrosia beetles. JOUR. ECON. ENT., **22**: 915–21.

Hubbard, H. G. 1897. The ambrosia beetles of the United States. U.S.D.A., Div. Ent., Bul. **7**: 9–30.

Mote, D. C. 1935. Tree borers and their control. Oreg. Agr. Expt. Sta., Circ. **110**.

Range Lizards as Insect Predators

GEO. F. KNOWLTON, *Utah Agricultural Experiment Station, Logan*

Fifty-nine sagebrush swifts, *Sceloporus graciosus graciosus* (B.-G.), were collected in south Cedar Valley, Tooele County, Utah, on May 29, 1941. These were taken among sagebrush, *Artemisia tridentata* and rabbit-brush, *Chrysothamnus nauseosus* and *C. viscidiflorus*, in a foot-hill area recently dusted for Mormon cricket control. The control program had been so effective that only an occasional living cricket was seen by the collectors, yet 23 of the stomachs (39 per cent) each contained a third or fourth instar *Anabrus simplex* Hald. nymph, or recognizable fragments. It was estimated that more than 500 lizards per acre were present, suggesting that this common swift undoubtedly is an important natural supplementary control factor. None of the approximately 20 smaller, immature lizard specimens taken at this time had recently eaten *A. simplex*, probably because *Anabrus* nymphs were large, and smaller insects could be more readily ingested.

Additional insect food in the lizard stomachs consisted of the following:

THYSANURA 3
COLLEMBOLA 14
ORTHOPTERA—
Grasshopper nymphs, 35 in 26 stomachs,
Gryllus assimilis (Fabr.) 1
Stenopelmatus longispina Bruner 2.
ISOPTERA 2
NEUROPTERA 1 (Chrysopidae)
CORRODENTIA 2
TRICHOPTERA 1
THYSANOPTERA 2
HEMIPTERA 181—
Pentatomidae 5—1 *Brochymena* and 1 *Thyanta custator* (F). included
Corizidae 1 (*Corizus hyalinus* (F.)
Lygaeidae 21—*Nysius ericae* (Sch.) 14, *Lygaeus reclivatus* Say 3, *Geocoris decoratus* Uhler 3, and 1 *G. atricolor* Montandon
Reduviidae 4—*Reduvius personatus* (L.), *Sinea diadema* (F.) and *Zelus socius* Uhler included
Nabidae 1—*Nabis alternatus* Parshley
Miridae 57 (6 nymphs)—*Lygus elisus* Van D. 2, *L. hesperus* Knight 3, *Adelphocoris superbus* (Uhler) 1
Corixidae 1
HOMOPTERA—188
Cicadellidae 57 (13 nymphs)—*Eutettix tenellus* (Baker) 3 (1 nymph)
Cercopidae 8—*Clastoptera delicata* (Uhler) 2
Membracidae 10—4 *Leioscyta ferruginipennis* (Godg.) and 1 *Campylenchia latipes* (Say)
Fulgoridae 3, *Scolops sulcipes* Say
Chermidae 8
Aphididae 44—6 *Macrosiphum coweni* (Hunter), 3 *M. escalantii* Knlt., 1 *M. pisi* (Kalt.), 1 *M. euphorbiae* (Thos.), 1 *Epameibaphis atricornis* G.-P., 1 *Clavigerus bicolor* (Oest.), 1 *Aphis carbocolor* Gill. and 1 *A. minutissima* G.-P.
COLEOPTERA 260 (11 larvae)—
Carabidae 6 recognizable
Silphidae 4
Staphylinidae 2
Histeridae 1, *Hister semiruber* Casey
Meloidae 1
Anthicidae 1
Elateridae 4 (one a larva)
Buprestidae 4
Dermestidae 1—*Dermestes lardarius* L.
Coccinellidae 6—4 *Hippodamia convergens* Guerin, 1 *H. spuria* Lec., and 1 *Exochomus marginipennis* Lec.
Tenebrionidae 3
Scarabaeidae 28—14 *Aphodius granarius* (L.), 9 *A. distinctus* Hald., and one large *Phyllophaga* adult
Lucanidae 1
Cerambycidae 3
Chrysomellidae 28 (6 larvae)—1 *Zygogramma exclamationis* F. and 3 fleabeetles
Rhipiphoridae 2
Curculionidae 16 in 11 stomachs
Scolytidae 2
LEPIDOPTERA 76, of which 73 were larvae including several armyworms and other species of cutworms
DIPTERA 99—11 Tipulidae, 3 Chironomidae, 1 Asilidae, 3 Stratiomyiidae and one *Drosophila*
HYMENOPTERA 1,168—489 ants of which *Pogonomyrmex occidentalis* (Cresson) was second in abundance only to species of *Formica*
5 wild bees, 1 bumblebee
Mutillidae 1, Chrysididae 1, Vespidae 1, Chalcidoidea 1
Insect Eggs, 93 in 4 stomachs
Spiders, 29 in 18 stomachs
Red mites, 14 large forms in 6 stomachs.

Also sage leaves and other plant fragments and a weed seed, as well as many insect fragments along through the digestive tract and in a large rectal mass. Many of these were still recognizable, some still after defecation. Such well known species as *Eutettix tenellus*, *Nysius ericae* and *Hippodamia convergens* were included among these.

Ten *Sceloporus g. graciosus* were collected in Diamond Canyon, Juab County, Utah, on June 21, 1941, in a sage area which had been treated to control the Mormon cricket. Three large *Anabrus simplex* nymphs, besides 2 adult and 15 nymphal grasshoppers were included among the insect food present. An additional swift collected at Government Creek, Utah, May 29, 1941, had eaten four nymphal *A. simplex*.

A large female horned-toad, *Phrynosoma douglassii ornatissimum* (Girard) was collected at Government Creek Canyon, in Tooele County, May 29, 1941, in a sagebrush area in which Mormon cricket control had recently been carried on. The bulging stomach of this lizard held 1 fourth-instar *Anabrus simplex* besides 3 large Tenebrionidae, 4 of the large *Ophryastes latirostris* Lec. weevils, 1 small *Hister semiruber* Csy. and fragments of two other beetles; 1 Mutillidae, *Dasymutilla klugii* (Gray) (Det. Dr. C. E. Mickel) and 2 harvester ants. Examination of the large bulges along the intestine revealed 4 additional *O. latirostris* weevils still largely intact, heads and body parts of 7 ants, 2 Hemiptera, one a Pentatomidae, besides numerous parts of insects belonging to other groups.

Examination of two *Phrynosoma d. ornatissimum* stomachs from specimens collected in Diamond Canyon, Utah, June 24, 1941, disclosed 1 *Anabrus simplex* nymph, 1 grasshopper nymph; 21 Hemiptera, 20 being *Nysius ericae* (Sch.); 1 leafhopper and 1 aphid; 1 *Pipunculus* fly; 11 beetles and 267 Hymenoptera, 257 being ants and 3 of the others wild bees.—5-19-42.

An Insect Rearing Box with Electric Barriers

M. C. SWINGLE and A. M. PHILLIPS, *U. S. Department of Agriculture, Bureau of Entomology and Plant Quarantine*

A major problem in the laboratory rearing of insects is the designing of suitable cages to confine the insects. Somehow these never seem to be entirely satisfactory and are continuously undergoing adjustment or reconstruction. In a recent paper (1941) equipment and methods were described which were used prior to 1940 for rearing insects at the Florida laboratory of the Division of Control Investigations, Bureau of Entomology and Plant Quarantine. As the rearing boxes described in the former paper have been replaced to a large extent by an electric rearing box developed in 1940, the present paper will describe the equipment now being used.

The new rearing cage is an open, shallow box with electrically charged barriers on the inside upper edge, which effectively prevent the escape of crawling insects from the box. The unit is not a cage in the usual sense of the word, but rather a continuous barrier placed about the feeding insects. The advantage of this type of rearing box is obvious, especially with regard to ease of caring for the insects and more natural light and aeration.

A brief description of the unit will serve to show its simplicity. The box itself (Fig. 1) is 21½ inches square and 5½ inches deep, with a 28-gauge sheet-metal bottom. After it had been firmly nailed together, the upper 2½ inches were cut off on a bench saw to form two units, as shown in fig. 1. This upper frame was fitted with corner blocks as shown, and two lengths of 1-inch brass linoleum strips were tacked around the inside of the frame, a 1/16-inch gap being left between the two strips. Two electric binding posts were installed through the strips and wood sides so that electric connections could be made easily on the outside of the box. This barrier frame was then replaced over the bottom and held in place with four screws.

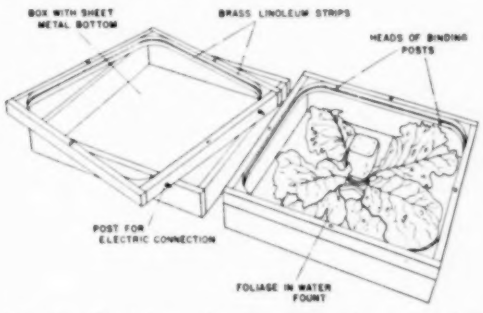
BOX WITH SHEET METAL BOTTOM
BRASS LINOLEUM STRIPS
HEADS OF BINDING POSTS
POST FOR ELECTRIC CONNECTION
FOLIAGE IN WATER FOUNT

FIG. 1.—Electric rearing boxes, showing method of construction and use.

The upper barrier frame was made detachable to facilitate cleaning, but this was found not to be essential. The use of the corner blocks was preferable to the alternative of extending the strips to the sharp 90-degree corner. As the lepidopterous larvae confined in the boxes usually secreted a web, over which they walked, they were able to escape in the sharp corners where this web did not contact the strips. As the webbing ultimately formed an insulation, it was found necessary to clean the entire lower strip daily.

A special rack holding nine of these boxes was constructed and mounted on large rubber casters for moving about the rearing room. This rack (Fig. 2) is 72 inches long, 54 inches high, and 22 inches deep. The two shelves built above the base are spaced 14 inches apart and were made by spacing a number of wooden strips betwen two lengths of 1-inch angle iron running the length of the rack on each side. The angle bars offer maximum strength, with a minimum of bulk to facilitate portability, and

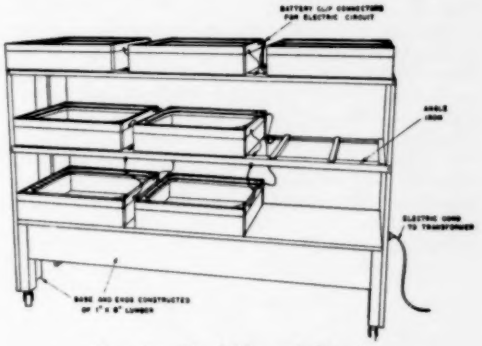
BATTERY CLIP CONNECTORS FOR ELECTRIC CIRCUIT
ANGLE IRON
ELECTRIC CORD TO TRANSFORMER
BASE AND ENDS CONSTRUCTED OF 1" x 6" LUMBER

FIG. 2.—Portable rack for nine electric-type rearing boxes.

permit light to enter the rearing boxes. These iron bars also act as electric terminals from the transformer, which is mounted under the base. A length of rubber cable connects with a wall outlet and permits movement of the rack about the room. The rearing boxes are supported by the wooden strips about ¼ inch above the angle-iron frames. Short lengths of rubber-covered wire, with zinc battery clips at each end, connect the box terminals to the side frames.

Ordinary bell transformers of 6 to 18 volts a.c. have been used to supply the current for charging the brass strips on the boxes. For most of the lepidopterous insects used, a 12-volt transformer was found very satisfactory. However, this voltage was not entirely satisfactory for third and fourth instars of the southern armyworm when under very crowded conditions, because such conditions caused the larvae to migrate and some individuals were electrocuted on contact. These larvae did not draw back quickly from the barrier as did the other species but regurgitated and were killed on the moist contact.

While experimenting with a "multivolt" transformer, the writers found that 6 volts was ample for confining fifth and sixth instars of the southern armyworm under all conditions and was effective with all instars when not crowded. However, this voltage was not sufficient to stop larvae that climb to the upper strip over the bodies of those crawling on the lower strip. To produce a deterring shock under these circumstances, 9 or 10 volts was necessary. Twelve volts caused the burning of larvae across the strips. Eighteen volts cause no injury to larvae of the melonworm, cross-striped cabbage worm, southern beet webworm, and Hawaiian beet webworm, because the insects drew back quickly on contact with the upper strips.

A similar box, with the upper contact built at right angles to and protruding over the lower one, was used very successfully with cockroaches. A 45-volt radio B battery worked very well for this pur-

pose, but the low-voltage bell transformers permitted some roaches to escape.

Many other adaptations of this electric barrier can be made to suit the problems at hand. For insects pupating in soil, several of the 2½-inch barrier strips have been fastened to plywood boards 21½ inches square with an opening 13½ inches square cut in the center. This opening permitted the larger barriers to be fitted over standard flats (1941) containing soil. After pupation occurred, the barrier was removed from the flat, and a screened oviposition cage was fitted in its place.

This method of isolation can be used, of course, on small boxes or even about benches in a greenhouse. With a dry cell and some method of protecting the strips from rainfall, barriers of various sizes could be used about small plots in the field. Most crawling insects can be confined with a barrier of this type, but the correct voltage and amperage must be used to avoid injuring the insects. Thin-legged insects, such as ants, aphids, and squash bugs, require much lower voltages than those suggested above; otherwise they are unable to withdraw appendages, which short the strips.—5-23-42.

LITERATURE CITED

Swingle, M. C., J. B. Gahan, and A. M. Phillips. 1941. Laboratory rearing of certain leaf-eating insects. JOUR. ECON. ENT. **34**(1): 90–95.

Some Quantitative Studies of *Lygus* Injury to Alfalfa Plants

G. F. MACLEOD and L. R. JEPPSON,
University of California, Berkeley

Injury to many agricultural crops has been recorded as a result of attacks by bugs of the genus *Lygus*. Recently there have been reported several studies on the effects of *Lygus* feeding on alfalfa, a crop which affords one of the principal breeding grounds for these insects in many areas of California. The *Lygus* bugs encountered most frequently in alfalfa fields have been either *L. hesperus* Knight or *L. elisus* Van Duzee. Of these two species the former is more abundant in central California and is the species which has been used in these initial studies. Sorenson (1932) (1939), Stitt (1940), and Carlson (1940) have shown that Lygus bugs cause flower drop and shriveled seed, thus materially reducing the yield and viability of alfalfa seed. Carlson (1940) has given evidence that the vegetative growth of alfalfa may be reduced as a result of the feeding of these bugs.

In 1939 studies were started to determine quantitatively the effects of Lygus feeding on alfalfa plants in terms of yield of hay. Selected seed of common alfalfa was sprouted in sand and grown in water cultures using ninety-six plants in eight tanks with twelve plants per tank. The plants were allowed to grow for sixteen weeks or through three cuttings before they were subjected to Lygus attack. Six days after the third cutting fifth instar nymphs were collected from the field and introduced into cages. Some plants were left without cages, some were caged with no bugs, and the others had two, four, eight or sixteen bugs places in cages. Each treatment was randomized as to location in the tanks and was replicated sixteen times in any given test. The cages and insects were left undisturbed until the

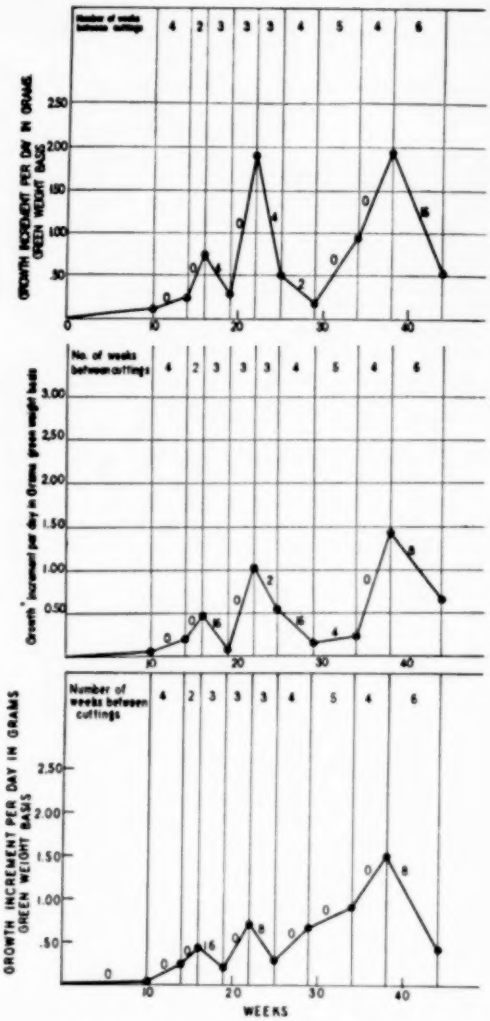

FIG. 1.—Three typical case-histories of individual plants.

plants were cut. Many of the insects died a few days after they were introduced but the results indicate that this variable was not a serious obstacle. When the plants were harvested the number of bugs both living and dead in each cage were counted. The insects were allowed to feed on the plants during the growth periods preceding the fourth, sixth, seventh, eighth, and tenth cuttings. The plants were permitted to grow without insects or cages during the periods preceding the fifth and ninth cuttings.

In taking the data at each cutting the plant tops were weighed as they were cut and immediately placed in an oven maintained at 50° C for 12 hours to prevent spoilage, after which they were dried at room temperatures until they reached a constant weight which was then recorded. Case histories of the green and dry weights of each plant were maintained for each cutting. Three typical plant case histories are shown in figure 1.

A normal, steady increase in growth increment per day as expressed in terms of green weight was

apparent with all plants in each of the first three cuttings. Following the introduction of *Lygus* nymphs to cages over the plants the average daily growth increment declined sharply in every case. During the period preceding the fifth cutting all of the plants were allowed to grow with no insects present and the remarkable recovery shown in the graphs occurred. There is thus afforded evidence that the injury to the previous cutting did not carry over, at least in the same order of magnitude, into the subsequent crops. After a second exposure to the insects in the growth-period previous to the sixth cutting all plants again showed large decreases in the daily growth increment. The same cycle of recovery and decrease in total green weight and consequent daily increment of growth was shown in subsequent cuttings.

From preliminary sections it appeared that *Lygus* injury to the vegetative growth consisted of a destruction of meristematic tissue at the growing tip with a resultant decrease in growth and a reduced yield of hay. The plants recovered quickly when insects were kept off them and were again injured when the insects were replaced at later growth periods. The age of the plants made little difference in the qualitative response to *Lygus* injury but marked quantitative differences were apparent. In general plants upon which 8 or 16 insects fed during the period preceding the fourth cutting failed to attain the daily growth increment of those plants on which the same number of insects fed but at later stages in the growth of the plants.

The results show that, in general both green and dry weights of plants were reduced in direct proportion to the number of insects which were permitted to feed upon them. The ratio of green to dry weight indicated that the differences in proportion of moisture in injured and uninjured plants followed no consistent trend.—2-18-42.

LITERATURE CITED

Carlson, J. W. 1940. Lygus bug damage to alfalfa in relation to seed production. Jour. Agr. Res. **61**:(11) 791–815.

Sorenson, C. J. 1932. Insects in relation to alfalfa seed production. Utah Agr. Expt. Sta. Circ. **98.**

Sorenson, C. J. 1939. Lygus bugs in relation to alfalfa seed production. Utah Agr. Expt. Sta. Bul. **284.**

Stitt, L. L. 1940. Three species of the genus Lygus and their relation to alfalfa seed production in southern Arizona and California. U. S. Dept. Agr. Tech. Bul. **741.**

A New Pest of Snapdragon and Verbena

EPHRIAM HIXSON, *Stillwater, Oklahoma*

In March 1940 a tingid, *Teleonemia nigrina* Champion,[1] was reported injuring snapdragon plants in a commercial greenhouse at Drumright, Oklahoma. Before this infestation was brought under control, the crop was almost a total loss. On April 20, 1941, native verbena being grown as an ornamental was found heavily infested with nymphs and adults of this same species. The verbenas were practically all killed by the insects. Since both snapdragons and verbenas are important ornamental plants, it was decided to study the habits and possible means of control of the insect.

This study was made at room temperature. Snapdragon plants growing in three-inch pots and snapdragon cuttings were used as the host. The pots with the plants were placed in wide-mouthed, pint fruit jars. The jars were partly filled with water so that the plants had uniform moisture and the roots could grow into the water through the drain hole in the pot. The wide, flat-bottomed jars made an ideal stand to prevent the pots tipping. The cuttings were placed in $\frac{3}{4}$ by 6-inch test tubes filled with water. A cotton plug was used to form a stopper for the tube and to hold the cutting upright. The test tubes were held upright in ordinary tube racks.

The insects were reared on the plants openly. They were found to be rather sedentary in habit and not easily disturbed, therefore cages were not necessary. Only the fourth instar nymph had a tendency to migrate, however, with a large population or during periods of extremely high temperature, there was a tendency for other stages to migrate. The adults took to their wings during adverse conditions, but were not at all strong fliers.

The female laid her eggs singly in the edge of the leaf parallel with the upper and lower surfaces. The insertion was accomplished by the female standing astride the leaf edge and pushing her blade-like, retractile ovipositor into the tissue. Some eggs were laid along the stem and in the leaf petiole. The egg puncture showed externally as a white speck in the form of a plug. The leaf tissue surround the egg gradually turned lighter in color as the time of hatching approached. The outline of the egg could be seen through the leaf tissue. See table 1 for length and stages and measurements of the life stages.

Table 1.—Measurements of the various stages of *Teleonemia nigrina* and the length of time spent in developmental periods.

		Nymphal Instars				
Stage	Egg	1	2	3	4	Adult
Length, millimeters	0.5	0.5	1.0	2.0	3.0	3 to 4
Duration, days	7	2.6	2.8	3.0	3.3	

The nymph upon hatching was yellowish in color. Feeding began soon after the nymph escaped from the egg. After feeding a short time greenish mottling and finally black areas appeared in the body. In the second and subsequent instars the nymphs were black and spiny. All nymphs and adults had red eyes. The life cycle required a total of 22 to 23 days divided as follows: egg 7 days, 4 nymphal instars 11.7 days and a preoviposition period of 3 to 4 days.

The plants were injured by the feeding of the insects. At the point where the tissue was pierced, a light colored, circular spot appeared. These spots soon whitened and finally turned brown. The spots coalesced and the leaf looked mottled, white rimmed or tip-burned. Wilting of both leaves and stems was common. The plant usually died, a leaf at a time, either from the top of the plant or the bottom until finally the entire plant was apparently dead. In some cases there was recovery by lateral shoots, but growth from these was weak and spindly. In most

[1] Determined by Dr. Carl J. Drake, Iowa State College, Ames, Iowa.

cases the plant did not recover. The rate at which the plants wilted and turned white indicated a toxic substance deposited in the feeding puncture. Conspicuous shiny black spots of excreta were deposited on the leaves during feeding by the insects, causing a splotting effect appearing much like flyspecks (Fig. 1).

Control of this tingid was accomplished on greenhouse snapdragons at Drumright, Oklahoma with a spray of *Lethane 384*, 1 part in 200 of water and potash fishoil soap. The spray was applied with an ordinary knapsack sprayer. The spray was syringed

FIG. 1.—A snapdragon plant showing typical injury.

off the plants after one hour to prevent burning. The operator had unsuccessfully tried control with nicotine as a spray, dust and fumigant, derris dust and a commercial pyrethrum spray.

In 1941 tests were made on 11 lots of the tingids containing a total of 189 insects of which 17 were fourth instar nymphs and the others adults. One lot of 10 adults dusted with superfine dusting sulfur showed no distress whatsoever and on being placed upon verbena leaves, immediately began feeding. At no time did any of them appear to be affected. Ten lots of the tingids containing from 10 to 20 individuals each, were dusted with pyrocide dust containing 7.5 per cent pyrethrins. In all tests and with little variation in effect there was a 100 per cent mortality. Paralysis occurred within five minutes, however, leg movement in some cases continued for as much as 12 hours. In no case was there recovery.—6-1-42.

Life-History of the Corn Sap Beetle in Rice

AUGUST I. BALZER, *U. S. Department of Agriculture, Bureau of Entomology and Plant Quarantine*

The corn sap beetle, *Carpophilus dimidiatus* F., has been found infesting brown, milled, and rough rice, rice bran, and rice polish in storage in the South. Although it is seldom found in sweet or freshly milled grain that is clean and dry, it frequently breeds in abundance in the bran and polish.

The rice-growing area on the gulf coast has a moist, almost subtropical climate. Average summer temperatures range from 80° to 90° and winter temperatures from 50° to 60° F. The range of atmospheric humidity is between 65 and 100 per cent the year around. In this area rice is milled at a moisture content of 14.5 per cent. The moisture content of rough and milled rice ranges from 12 to 14.5 per cent when stored. Rice bran and polish are ordinarily stored in a dry room at a moisture content of 10 to 15 per cent, but these products frequently become heavily infested by the corn sap beetle within a month after storage, because they turn rancid very quickly even under the best conditions. Brewers rice and rice screenings in good condition and containing 14 to 15 per cent of moisture also occasionally become infested by the corn sap beetle, especially when held for a considerable period. This insect is almost universally present in accumulations of rice and rice products in mill machinery and under mills and warehouses. Samples of rice stored in boxes in offices also frequently become infested.

Inasmuch as the literature concerning the corn sap beetle is meager, life-history studies have been conducted on this insect in relation to its rôle as a pest of stored rice. The data presented in this paper were gathered during the 4-year period 1937–1940. The beetles were reared in quart and half-gallon glass jars screened at the top and having a layer of damp sand in the bottom. The cages were kept in the laboratory during the summer and in an open garage during the colder periods of the year. In general, cracked rough rice was used as food.

The average longevity of the adult feeding on cracked rough rice under optimum conditions was found to be approximately 63 days during the summer. Several beetles lived for 90 to 117 days during this season, and overwintering specimens lived as long as 200 days. The female beetles frequently commence ovipositing within 24 hours after emerging and continue until shortly before death, although they deposit most of the eggs early in their adult life. The eggs are deposited loosely in the food material they happen to infest, from 175 to 225 eggs per female. The incubation period is apparently short; several lots of eggs were observed to hatch within 24 hours after deposition.

Under optimum conditions larvae mature and pupate in approximately 10 or 11 days. Under adverse conditions, however, they grow very slowly. Individuals reared on cracked rice having a moisture content of 10 per cent required 34 days to complete the larval stage, but most of the larvae failed to develop in rice with such a low moisture content. Numerous small larvae lived 6 days and a few 28 days, although without seeming to increase in size. A small percentage grew slowly to practically normal, mature larvae, but none pupated. These insects apparently all died in the prepupal stage.

After the larva has matured it burrows into the

soil, if soil is present, and pupates. In the rearing experiments sand, and in a few instances plaster of paris, was used in the bottom of the cages. Both were found to be satisfactory substitutes for soil. If no soil or substitute is present, the corn sap beetle is able to complete its life cycle in the food material in which it breeds. Survival was low, however, in cages without soil or soil substitute. During the summer under optimum conditions the pupal stage may be as short as 7 days; during the winter a pupal period of 140 days has been observed.

According to observations made with colonies started early in the fall and held in an open garage, the corn sap beetle may overwinter in both the pupal and the adult stages. In 1937–38 and 1938–39 only adults overwintered, but in 1939–40 the insect overwintered in both stages. The last winter was exceptionally severe. The average mean temperature for January was 42.3° F., or 11.2 degrees below normal, and for February 52.8° F., or 4 degrees below normal. There were 25 days with a minimum temperature of 32° F. or lower during the two months, the lowest temperature recorded being 12° F. Under conditions prevalent at Beaumont, Tex., the adult crawls during the winter but does not attempt to fly. It becomes more active during the first days in March and is frequently seen flying on warm days. Oviposition commences the first part of March. First-generation pupae have been found as early as March 19.

The effect of the moisture content of rice, used as food, on the development of the corn sap beetle was determined by attempting to rear this insect in rice the moisture content of which was maintained constant at several levels. The method used consisted of bubbling compressed air through sulfuric acid of suitable specific gravity to obtain air containing the desired humidity, and introducing it into a glass cage containing sterilized cracked rough rice of known moisture content, infested with sterilized eggs of the corn sap beetle. Following the method used by White (1937) in preparing fly larvae for treating osteomyelitis, the eggs were sterilized for 15 minutes in a solution of 1 part of mercuric chloride in 400 parts of saline solution containing 25 per cent of alcohol and 0.125 per cent of hydrochloric acid. It was observed that this insect was unable to complete its development in rice having a moisture content of 10 per cent, a small percentage completed development in rice of 12.7 per cent moisture content, and the optimum moisture content for development ranged between 15 and 33 per cent. A few larvae survived in rice with 38 per cent of moisture, but under natural conditions stored grain spoils when the moisture content is much lower than this. While the corn sap beetle was able to breed in putrefying food it developed much more rapidly on sterilized food such as was used in the experiment.

SUMMARY.—Investigations conducted at Beaumont, Tex., have shown that the corn sap beetle (*Carpophilus dimidiatus* F.), reared on cracked rough rice, may overwinter in both the pupal and adult stages. Oviposition commences early in March, females depositing from 175 to 225 eggs each. The beetles live about 63 days in summer and as long as 200 days in winter. First-generation pupae may be found by the middle of March. Under optimum summer conditions the life cycle may be completed in 18 days, whereas in winter it may extend over 150 to 200 days. The beetle prefers food of 15 to 33 per cent moisture content and can survive on food of higher or lower moisture content, but apparently it cannot mature to the adult stage in rice containing less than 10 per cent of moisture. The insect is able to breed in putrefying food, but develops more rapidly in sterilized food. The beetle pupates in soil, but it can complete its life cycle in the food material it infests if no soil is available.—6-10-42.

LITERATURE CITED

White, G. F. 1937. Rearing Maggots for Surgical use. Cultural methods for invertebrate animals, compiled by P. S. Galtsoff *et al.* Ithaca, N. Y., pp. 418–427.

An Additional Observation on the Biology of *Erynnia nitida*

STANLEY E. FLANDERS, *University of California Citrus Experiment Station, Riverside*

In a note appearing in the JOURNAL, Vol. 33, p. 947, it is stated that "Under natural conditions it is probable that overwintering *Erynnia* cannot complete its development until its host commences feeding in the spring." Recent observations prove this to be the case.

Twenty-two overwintering adults of the elm leaf beetle were collected at Manteca, California, on April 13, 1942. Dissections of one of these revealed that *Erynnia* had overwintered as a first instar larva. The rest of the beetles were placed in an outdoor cage and were fed fresh elm leaves daily, commencing April 14. Twenty days later on May 4, a full-fed larva of *Erynnia* was removed from another of the beetles. On May 5, this larva formed a puparium which yielded an adult female May 21. Whether more than two of the beetles contained parasites is not known since half their number died of disease.

Oviposition by the overwintering elm leaf beetles began May 3. It appears therefore that under field conditions *Erynnia* adults emerge only when the spring brood of host larvae are available for attack. —6-1-42.

Some Observations on the Effects of Sulfur Compounds Applied During Bloom on Bee Behavior[1]

F. R. SHAW and A. I. BOURNE, *Massachusetts State College, Amherst*

In some areas where the problem of apple scab is especially serious, the practise of applying a sulfur dust during bloom is becoming quite general. Apparently little thought has been given to the effects of such applications either as directly affecting bees or as repelling them and thus reducing the set of fruit.

Some preliminary experiments conducted in Massachusetts indicate that sulfur applied to bloom either as lime sulfur or as a dust will reduce the number of visits of bees. The experiments were conducted as follows. Flowers of the same variety, Arkansas, were arranged so that each bouquet had, as nearly as possible, the same number of blossoms at the same stage of maturity. Six such bouquets were selected. Of these two were treated with 400 mesh

[1] The authors do not wish to have anyone imply that sulfur is a good repellant to bees since we do not know the effects of this material on bees.

Table 1.—Arkansas blossoms visited by bees.

Time	Trial	Untreated	Lime Sulfur	Sulfur dust
12.00	1	19	4	4
12.30	2	18	6	2
1.00	3	30	10	5
1.30	4	33	8	8
2.00	5	22	12	8
2.30	6	25	19	9
3.00	7	19	19	5
3.30	8	21	14	6
4.00[1]	9	10	3	1
Totals		197	95	48
Ave. per trial		21.8	10.5	5.3
Ave. per min.		2.18	1.05	.53

[1] Experiment had to be concluded because of an approaching thunder storm which reduced bee activity during the last trial.

dusting sulfur; two received lime sulfur at the rate of 1–50, and the remaining two were untreated. The bouquets were then placed on a long table close to the college apiary.

Counts were obtained of the number of bees visiting the treated and untreated bouquets over 10 minute intervals. Then the bouquets were shifted so as to eliminate, so far as possible, any trained response. No counts were then taken until the bees seemed to be working the untreated foliage freely. The data obtained are reproduced herewith.

The bouquets were kept in water overnight and exposed to bees the following day. The bees seemed to work all lots equally well at that time.

The above data, while admittedly incomplete, does indicate that the practise of applying a sulfur dust during bloom may be questionable. Ordinarily the sulfur would not be applied except when apple scab is especially serious. The conditions favoring scab development act to retard bee activity. i.e., rainy weather: under such conditions it would seem questionable to take the risk of repelling bees by the application of some material, which from the data above, does reduce the attractiveness of blossoms to the bees.

One further point needs emphasis. We do not know exactly what the effects of sulfur compounds may be on bees. Brittain et al. 1933 have stated that sulfur applied either in the elemental form or as lime sulfur caused severe dysentery to bees. Apparently the seriousness of this as regards the future development of the colony is not determined.—5-8-42.

Prionus laticollis (Drury) in a Subterranean Wooden Duct for Telephone Cables

W. B. BECKER, *Massachusetts Agricultural Experiment Station, Amherst*

Failure of a telephone line in Springfield, Massachusetts, led to the discovery of three large larvae of the broad-necked root borer, *Prionus laticollis* (Drury) in one side of an underground wooden telephone duct made of southern pine. The lead covering on the cable inside the duct had a hole chewed through it at the point where the insect-injured wood occurred. Moisture entered the cable through the hole and caused a short circuit.

The duct had an outside width of four and one-half inches and contained a hollow core three inches in diameter. It was divided into six-foot sections. Each section had been treated with creosote before installation. In the injured section, however, the side which was infested with the larvae contained little or none of the wood preservative. Examination of the growth rings in the wood showed that the insect-infested side of this duct came from the center of the tree from which it was cut, indicating that it contained heartwood. Heartwood, of course, may not be expected to absorb creosote as well as sapwood. In addition, leaching may have helped to remove some of the creosote after the duct was placed in the ground. However, the other side of the duct was well impregnated with creosote and showed no insect injury. The duct was placed in service in 1930. The cable in it failed in September 1941.

The injury occurred three feet below the ground level in a lawn area, no trees or shrubs being in the immediate vicinity at the time of failure. The soil below the sod was sandy. The telephone workmen were reported to have encountered no roots while digging. The homeowner, however, stated that a tree had grown adjacent to the point of injury but had been removed several years before. Adjoining sections of the duct were not unearthed for examination.

A somewhat similar case occurred in the adjacent town of Longmeadow the year before. In this latter case there were trees and shrubs nearby. Larvae from both localities were identified as *Prionus laticollis* (Drury) by Dr. W. H. Anderson of the Division of Insect Identification, Bureau of Entomology and Plant Quarantine, Washington, D. C.—8-1-42.

A SERVICE ROSTER OF ENTOMOLOGISTS

Secretary Cory, of our Association, and Secretary Mickel, of the Entomological Society of America, plan to have on display at the annual meetings of the two organizations in New York in December, a roster of all entomologists known to be in service in any of the branches of the armed forces of the Nation at that time. All readers of this *Journal* are urged to send details concerning any of their entomological acquaintances known to be in the service. Present location, rank and date of induction into the service are especially important.

Please send any such information as early as possible to Dr. E. N. Cory, College Park, Maryland, or Dr. Clarence E. Mickel, University Farm, St. Paul, Minnesota.

JOURNAL OF ECONOMIC ENTOMOLOGY
Official Organ American Association of Economic Entomologists

Vol. 35 August, 1942 No. 4

Entomologists and the War

IN THESE TIMES the Government of the United States needs the cooperation, either active or otherwise, of every citizen in the country. This includes entomologists regardless of the type of work upon which they are engaged. And such cooperation can be made effective if every entomologist will reexamine his activities and replan them so far as possible to meet the war requirements, even to the point of sacrificing undertakings. This applies to research, teaching, extension, and quarantine problems. Many entomologists have already done this, but others have not, due to the difficulty of deviating from current behavior patterns, uncertainty as to the length of the war, caused by conflicting press releases and to the fact that they consider their activities too remote to be of aid in the war effort.

It is my belief that much could be accomplished if every entomologist would consider himself as a member of a committee made up of the entire Association, the duties of each member being to adjust his activities and to make every effort to confine them to the war needs of our Government.

When I appointed the Committee on the Coordination of Entomology with the War Effort, I was of the opinion that it would serve mainly to remind the membership of the Association of their responsibilities in helping to win the war. I believed that entomology was already organized and doing what it could to serve the country, through its associations and their branches, the regional plant boards, and because of the way entomological work is set up on a state basis.

However, the reports of the Committee which have appeared in the April and June issues of the JOURNAL have convinced me that more is needed. Although our organizations are already sound and cooperative, more cooperation is needed if the Government's goals for increased production of certain commodities are to be met, if our growing crops are to be protected from insects, if stored foods are to be fully protected, if military and civilian needs for entomologists are to be adequately supplied, if insecticides are to be conserved, if research programs are to be changed, if teaching is to be reorganized, if control and regulatory activity are to be modified, if extension entomology is to be expanded and if many other things necessary to win the war are done.

In order that this additional cooperation may be forthcoming and so that it will bear fruit, I am asking every member of the Association to consider himself as a member of a Committee of the Whole and to consider the Committee on the Coordination of Entomology with the War Effort simply as a small functioning group necessary to facilitate the action of the Committee of the Whole. To this end I shall welcome suggestions relative to entomology in its relation to the war effort, particularly those bearing upon the problems which are confronting the functioning group. I hope that all members will read carefully and thoughtfully, both reports of the Committee in the April and June issues and that they will cooperate and participate fully in the proposed programs, with such modifications as are necessary in different regions.

Some entomologists are in the armed forces, some have special assignments connected with camp sanitation, protection from disease-carrying insects, etc., some are engaged in research concerned with reduced dosages for the control of certain species, or with substitute insecticides, some are engaged with camp and warehouse fumigation, some with increased crop production through insect control, some with revised recommendations bearing on the supply of insecticides, some with a stepping up of biological control, some with adjusting their teaching courses to the war needs. All such practices have a direct or indirect bearing upon the war. And if the best of these practices can be agreed upon and dis-

seminated more widely through the plan of cooperation proposed by the Committee in the June issue, entomology will demonstrate more fully its importance in human welfare at a time when its help is most needed.

The scientific ability and the technical knowledge of all entomologists should be fully used in the effort to win the war and to protect resources that will be needed after the war. Even though it is not a glamorous job and even though the nation does not fully appreciate the value of entomologists either in peace or war, there is a special job to be done, and as loyal citizens, the members of the American Association of Economic Entomologists will do their part without special urging or recognition. Canadian entomology has been on a war basis for some time and it is vitally necessary that the entomologists of this country recognize the need for immediate action. I therefore again urge all members to cooperate fully with the Committee on the Coordination of Entomology with the War Effort, under the chairmanship of Dr. E. F. Phillips, Ithaca, N. Y. This Committee has the interest of the country at heart, and needs your support.

H.B.W.

OBITUARY

Lynn G. Baumhofer
1895–1942

Lynn G. Baumhofer, Associate Entomologist, Division of Forest Insect Investigations of the Bureau of Entomology and Plant Quarantine, died at Washington, D. C. on June 13, 1942, following an illness of about two months. He was born at Montevideo, Minn., Sept. 19, 1895 where he attended the public grade and high schools. He received his B.S. degree in Forestry at the University of Minnesota in 1925 and his M.S. degree in Entomology from the same institution in 1930.

After finishing high school in 1913 Mr. Baumhofer spent several years at various jobs and served one year (April 1918–March 1919) as a private in the Army with the 71st Balloon Squadron at Richmond, Virginia. He entered Hamline University in St. Paul Minn. in the fall of 1919 but transferred to the University of Minnesota in 1920. His university training was interrupted by periods when he found it necessary to work and earn money for continuing his education. His first position in entomology was during the summer of 1924 when he was employed as a Field Assistant in the Bureau of Entomology and assigned to work on the spruce budworm in northern Minnesota. After graduating from the University in March 1925 he was sent by the Bureau to Halsey, Nebraska to study the pine tip moth which was causing serious damage to pine plantations on the Nebraska National Forest. He continued on this work, first as Field Assistant and later as Junior Entomologist, except for short periods of graduate study, until August 1932 and during that time was active in releasing and establishing parasites that proved effective in controlling the tip moth. In June 1930, he was appointed Assistant Entomologist and assigned to the Coeur d'Alene, Idaho, Forest Insect Laboratory where he devoted most of his time to studies of bark beetles in addition to continuing some of his work at Halsey. He was promoted to Associate Entomologist and transferred to Denver and then to Fort Collins, Colorado, in 1935. There he worked on insects affecting shelterbelt plantings and on the Black Hills beetle. He was transferred in the fall of 1937 to Washington, D. C., where he devoted the major part of his time to handling the voluminous correspondence on insects affecting shade trees and ornamental shrubs.

Mr. Baumhofer had a host of friends and acquaintances who admired and respected him for his quiet, unassuming manner and his painstaking thoroughness in all his work. In the professional field his friends included many foresters as well as entomologists. He had recently completed, as co-author with Dr. C. A. Weigel, a manuscript for a new Farmers' Bulletin on insects affecting ornamental plants. This bulletin, when published, will undoubtedly prove to be one of the most useful publications of the Department.

Mr. Baumhofer was a member of the American Association of Economic Entomologists, the Entomological Society of Washington, and the Society of American Foresters. During the past year he served as treasurer of the Entomological Society of Washington, with the same efficiency that characterized his other work.

He is survived by his wife and one child.—7-17-42

L. W. ORR, R. A. ST. GEORGE and F. M. WADLEY

Name that Animal, by E.C. Driver, 119 Prospect Street, Northampton, Mass. Published by the Author. $5.00.

Name That Animal should have an appeal to anyone interested in knowing and recognizing the common land and fresh-water animals. The book is intended primarily to aid the non-specialist and beginner in identifying the common animals he meets in the field. This necessitates the use of visible external characters as much as possible and avoids the use of characters hidden and difficult to see that can be discovered only by dissection. The work is the result of several years of active study in the field and intensive examination of accurately identified specimens from various regions of the United States. Dr. Driver has rendered a real service in his book to the beginner, in fact, even to the taxonomist beyond his special field. A list of specific references is appended to each section to assist those wishing to study or specialize in groups of animals in greater detail than is covered by the scope of this book.

As the title indicates, Name That Animal is primarily a book to aid in the identification of animals. It contains 527 pages, 400 of which are devoted to classification and keys, and the balance to discussion and references. One hundred thirteen of the above 400 pages are full-page plates by Mrs. Olive Driver containing nearly 700 individual line drawings. The sketches are most helpful to the beginner, but unfortunately are not cross-referenced in the keys. It would have assisted the user if the actual size of the animal had been indicated on the sketches. The lack of an index is somewhat disconcerting, but is not as necessary in a work of this nature as in a general text. The book is of convenient size, approximately 6×9 inches. The type is of suitable size making the keys very legible. The work is relatively free of typographical errors.

Seventeen chapters are included in the book. The introductory portion of each chapter contains general information such as, general characteristics of the phylum, food habits, methods of reproduction, and suggestions for collection, culture, and preservation of specimens. This general discussion is followed by an outline of the classification of the phylum or group, listing the major characters of each subdivision. The remainder of the chapter or section is devoted to the keys and plates for identification.

Each chapter deals with a specific subject or group of animals as follows: (1) introduction, (2) protozoa, (3) moss-like and jelly-like animals, (4) rotifers and gastroticho, (5) worm-like and leech-like animals, (6) mollusks, (7) arthropods, (8) fishes, (9) salamanders, (10) frogs and toads, (11) lizards, (12) snakes, (13) turtles, (14) birds, (15) mammals, (16) eggs, and (17) tracks. Many users would welcome a chapter on scatology, since the droppings are often the most evident sign of the presence of certain animals.

The introductory chapter contains keys to the major divisions of minute aquatic animals, macroscopic land and fresh-water animals, and the principal large groups of vertebrates based on skull characters. The keys in Chapters 2 to 7 lead to the identification of the common or principal genera in most instances, although species are included in some keys. Chapters 8 to 13 and 15 contain keys that identify to species in most instances. The section on insects in Chapter 7 contains keys to the orders only, while Chapter 14 on birds is likewise short, and without keys, since specialized treatises are more useful for identification in these groups. Special keys to genera are included in Chapters 12 and 15 based on color patterns of snakes and skulls of mammals.

Chapters 16 on animal eggs and 17 on animal tracks contain only brief treatment of the subjects. No keys are included in these sections.

HARVEY L. SWEETMAN

NOTES

The American Commission on Scientific Nomenclature in Entomology

The disturbed condition of the world during the last few years has interfered with the activities of the International Commission on Zoological Nomenclature and there is no prospect that this Commission will again function successfully for several years to come. Entomologists in the United States have felt that this situation should not be allowed entirely to stifle progress in the development of nomenclature and the clarification of nomenclatorial problems. At the meetings of the Entomological Society of America and the American Association of Economic Entomologists in San Francisco, in December, 1941, a plan was adopted which called for the establishment of an American Commission on Scientific Nomenclature in Entomology.

In accord with the terms of this plan, Mr. C. F. W. Muesebeck and Professor G. F. Ferris were appointed to organize the Commission. That organization has now been completed and the Commission is ready to function. It includes Prof. J. C. Bradley, of Cornell University; Mr. W. J. Brown and Mr. G. Stuart Walley, of the Division of Entomology of the Department of Agriculture of Canada; Prof. G. F. Ferris, of Stanford University; Prof. T. H. Hubbell, of the University of Florida; Prof. H. B. Hungerford, of the University of Kanass; Dr. E. G. Linsley, of the University of California; Prof. Clarence E. Mickel, of the University of Minnesota; Mr. C. F. W. Muesebeck and Mr. P. W. Oman, of the United States Bureau of Entomology and Plant Quarantine; Prof. A. G. Richards, Jr., of the University of Pennsylvania; Dr. Herbert H. Ross, of the State Natural History Survey of Illinois; Prof. C. W. Sabrosky, of the State Agricultural College of Michigan; Dr. R. L. Usinger, of the College of Agriculture of California. Prof. G. F. Ferris has been elected Chairman.

The Commission will receive, consider and advise upon such nomenclatorial problems as are presented to it. All acts of the Commission will be in harmony with the International Rules of Zoological Nomenclature, although recommendations for the clarification, extension and improvement of these rules may be made. The Commission will report to the two parent societies at their next annual meeting. Communications concerning matters within the province of the Commission may be addressed to any of its members.—6-1-42.

SECRETARY OF AGRICULTURE WICKARD MEETS WITH CORN BORER WORKERS

The notable increase of the corn borer in the north central states and the threat to the corn belt was responsible for a meeting of those interested in corn borer control, called by Secretary of Agriculture Wickard. The meeting held in Chicago, July 28, was attended by Secretary Claud Wickard; Ex-Governor Townsend, of Indiana, now Director of Agricultural Conservation of AAA; Deans Rush of Illinois and Reed of Indiana; Director of Extension, U. S. D. A., M. L. Wilson, and the following entomologists: Ray Hutson, W. P. Flint, J. J. Davis, Frank Wallace, L. L. Huber, T. H. Parks, G. E. Lehker, P. N. Annand, W. A. Baker, and C. M. Packard.

E. C. Auchter, Director of Research of the U. S. Department of Agriculture, was chairman of the meeting. The deliberations resulted in drawing up a set of suggestions for corn borer control, stressing four points, based on previous research and the conditions prevailing in the corn belt, as follows: Destruction of overwintering borers, date of corn planting, resistant and tolerant hybrids, and modification of cropping practices.

The conference also considered extension methods to be used by the states involved to secure maximum adoption of the recommended controls.—7-31-42.

J. T. DAVIS, Lafayette, Indiana

WHITE-FRINGED BEETLE QUARANTINE MODIFIED

The white-fringed beetle quarantine regulations were revised effective May 9, 1942, to extend the regulated areas in Alabama, Florida, Louisiana, and Mississippi, to include several small areas which are for the most part in the vicinity of old infested areas; to release an area of approximately 84 square miles in the vicinity of Monroeville, Alabama; to add to articles that are restricted throughout the year, lily bulbs, grass sod, peanut hay, and nursery stock including greenhouse-grown annuals and perennials; to lift the restrictions on sweet potatoes, peas, and beans, and to make other modifications.

Under administrative instructions of the Chief of Bureau, certain articles were lifted from the restrictions of the white-fringed beetle quarantine, part of the year, and the methyl bromide treatment of soil masses for white-fringed beetles was modified as to dosage and temperature. These instructions are covered under circulars BEPQ 485, Ninth Revision, effective May 11, and Supple ment No. 1, BEPQ 503, effective May 6, 1942.

PERMIT DIVISION MOVED TO HOBOKEN

The unit of the Division of Foreign Plant Quarantines which issues permits for importations of plants and plant products under the various foreign plant quarantines and orders was moved from Washington, D. C., on May 13, 1942, to the Plant Inspection House at 209 River Street, Hoboken, New Jersey. This work is now under the general supervision of Mr. George G. Becker, Senior Entomologist in Charge, and the activities connected with the issuance of permits, as well as the inspection of imports at the Hoboken building, are combined to form the Import and Permit Section of that Division, which is under the direction of Mr. E. R. Sasscer.

PEACH MOSAIC QUARANTINES REVISED

The embargoes on shipments of plum nursery stock have been lifted in current revisions of the peach mosaic quarantines of Arizona, Colorado, Oklahoma, and Texas and it is understood that such action is being taken by the States of Utah and New Mexico. The State of California prefers to retain the embargo type of restrictions on all host plants of the disease. The embargoes as to plum stock were originally placed because such trees have been known to be carriers of the disease in symptomless form indistinguishable from peach mosaic. Federal and State research workers, after careful study now point out that no instance of natural spread of the mosaic from plum to peach has yet been found. The States have, therefore, indicated their acceptance of the provision that all host plants including plums, prunes, almonds, and apricots may be shipped under certification based on annual inspection of peach and nectarine trees within 1 mile of nurseries and of budwood sources, and removal of infected trees by May 15. It is believed that the peach and nectarine trees in the mile-zones will serve as an index of the presence of any mosaic infection. The pre-defoliation inspection in the fall is discontinued, and emphasis is placed upon the selection of budwood which must be cut under inspector supervision and certified.

The regulated areas are extended to include Johnston County, Oklahoma, and the Texas counties of Ellis, Fannin, Fisher, Parker, Runnels, and Taylor.

The Oregon quarantine pertaining to European corn borer was amended effective May 20, 1942, to eliminate cosmos, zinnia, hollyhock, and oat and rye straw from the list of host plants of the borer.

SWEET POTATO WEEVIL QUARANTINES

California sweetpotato weevil quarantine proclamation (No. 9) was revised effective June 15, 1942, to add to the area designated as infested Butler County, Ala., Forrest and George Counties, Miss., and the Kentucky counties of Ballard, Carlisle, Hickman, Fulton, and Graves. There were removed from the infested area the Texas counties of Gregg, Shelby, and Smith.

JAPANESE BEETLE REGULATIONS AMENDED

The administrative instructions pertaining to treatment requirement of plants to free them from infestation by the Japanese beetle were modified by reducing the period of treatment with paradichlorobenzene from five to three days and by reducing the dosage of lead arsenate in field treatment. These modifications are covered respectively in Supplement No. 5 of BEPQ 499, effective May 18, and by revision effective May 7 of Supplement No. 4 to the above circular.

DR. UPHOLT TO FLORIDA

Dr. Wm. M. Upholt, who has been located at Clemson College, South Carolina, has resigned and has accepted a position as entomologist with the California Spray-Chemical Corporation. Dr. Upholt's new address will be at Orlando, Florida, 736 Hayden Lane, where he has been located since July 15.

PROCEEDINGS OF THE TWENTY-SEVENTH ANNUAL MEETING

PACIFIC SLOPE BRANCH AMERICAN ASSOCIATION OF ECONOMIC ENTOMOLOGISTS

University of Utah, Salt Lake City, Utah June 17–18, 1942

The 27th Annual Meeting of the Pacific Slope Branch was quite successful, even though travel restrictions caused a reduced attendance. The interest in the papers and participation in the discussions seemed to be greater on account of the lessened attendance.

The outstanding address of the meeting was given by Dr. P. N. Annand, on "Insect Problems Affecting Food Production." He stressed the importance of the various problems now facing the entomologists in connection with our national efforts to produce sufficient food for ourselves and our allies.

The discussion on "What can we as entomologists do to be of most service to our country?" was participated in by most of those present and brought out many interesting viewpoints. It was shown that the entomologist has a place in the armed forces where his training and experience are needed in connection with insect problems affecting the health of the military units, and in the protection of food or other stores from insect damage. It was also brought out that the efforts of entomologists in civilian life, whether in research, teaching, or extension, should be concentrated on the control of insects affecting food and other materials needed by the military and civilian forces in our war effort.

Two very fine colored motion pictures were shown, one by Dr. A. J. Cox, Chief of the Division of Chemistry of the California Department of Agriculture, the subject of which was "The Story of Economic Poisons." This showed the making and application of our various economic poisons. The other motion picture was "Combat," by the General Chemical Company, showing the fight against insect pests and plant diseases in the principal fruit and vegetable producing areas of the country.

The total attendance was 65, and the following members were among those present:

Annand, P. N.	Washington, D. C.
Brindley, T. A.	Moscow, Idaho
Campbell, Roy E.	Alhambra, Calif.
Dohanian, S. M.	Eugene, Oregon
Douglass, J. R.	Twin Falls, Idaho
Doyle, E. T.	San Francisco, Calif.
Fenton, Alfred	Houston, Texas
Fracker, S. B.	Washington, D. C.
Fronk, Don	Ogden, Utah
Johnson, Esler	San Francisco, Calif.
Knowlton, G. T.	Logan, Utah
Lane, Merton C.	Walla Walla, Washington
Mote, Don C.	Corvallis, Oregon
MacLeod, G. T.	Berkeley, California
Peay, W. E.	Logan, Utah
Richards, Claude A.	Arcadia, Calif.
Sorenson, C. J.	Logan, Utah
Webster, B. L.	Pullman, Washington
Wampler, E. L.	El Segundo, Calif.
Yust, Harold R.	Whittier, Calif.

BUSINESS SESSION.—Committees appointed at the opening session reported at the final business session, as follows:

Resolutions:—Be it resolved that the very sincere thanks of the members of the Pacific Slope Branch of the A.A.E.E. be extended to the many agencies who have contributed to the enjoyment of this meeting—Newhouse Hotel, Wasatch Chemical Co., A-1 Sugar Co., Fisher Brewing Co., all of Salt Lake City, and the Tobacco By-Products & Chemical Corp. of San Francisco, and Texas Gulf Sulphur Co. of Houston, Texas. Be it further resolved that the group express its appreciation for the efforts of the local members, particularly Dr. George Knowlton and Prof. C. J. Sorenson, Dr. Don N. Rees, Mr. W. E. Peay, and Dr. V. M. Tanner, for the successful handling of the innumerable details connected with the planning and conduct of the meeting. Be it further resolved that our thanks be extended to all those who arranged the delightful organ recital given by organist Setreiner on the Tabernacle organ, and the reception at the Lion House.

Respectfully submitted,
Resolutions Committee,
E. L. WAMPLER
ALFRED FENTON
G. F. MACLEOD, *Chairman*

TREASURER'S REPORT

June 18, 1941, Balance on hand			$16.03
July 28, 1941, Refund for 1940–41 expenses			48.58
Express and postage on proceedings		$ 1.71	
P stage and postal cards		2.40	
Mailing announcements		9.60	
Mimeographing notices		7.25	
Multigraphing program		10.82	
	Expenditures	$31.78	
June 13, 1942	Balance on hand	32.83	
		$64.61	$64.61

Accounts audited and approved by J. R. DOUGLAS, S. M. DOHANIAN, and ROY E. CAMPBELL, *Secretray-Treasurer.*

Vice-President S. B. Fracker brought greetings from President Weiss, and regrets that he could not attend. He also reported on certain resoutions passed at the 1941 Pacific Slope Branch meeting, and commented on the recent questionnaires sent out by the Joint Committee for Effective Utilization of Entomological Personnel and Facilities during the War, stressing the importance of filling out the form fully and sending it in promptly.

New officers elected were:—

Chairman: MERTON C. LANE, *Walla Walla Washington*
Vice-Chairman: K. W. GRAY, *Corvallis, Oregon*
Secretary-Treas.: ROY E. CAMPBELL, *Alhambra, Calif.*

It was announced that the 1943 meeting would be held at Oregon State College, Corvallis, Oregon, during the 3rd week in June.

ROY E. CAMPBELL, *Secretary*

Notice to Contributors

Engravings for the February and April numbers of the current volume of the Journal are now available. Any contributor who desires to secure his engravings should apply for them within sixty days of the publication of this notice. It is now our policy to put the metal back in use by turning in unwanted engravings promptly. Earlier engravings are no longer available, having been returned to the engravers so that the metal might be used again.